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DEVELOPMENT DOCUMENT FOR EFFLUENT LIMITATIONS GUIDELINES AND NEW SOURCE PERFORMANCE STANDARDS FOR THE CANE SUGAR REFINING SEGMENT OF THE SUGAR PROCESSING POINT SOURCE CATEGORY

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This document presents the findings of an extensive study of the cane sugar refining industry for the purpose of recommending Effluent Limitations Guidelines, Federal Standards of Performance, and Pretreatment Standards for the Industry for the purpose of implementing Sections 304, 306, and 307 of the "Act."

Effluent limitations guidelines are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available" and the "Best Available Technology Economically Achievable" which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The "Standards of Performance for New Sources" set forth a degree of effluent reduction which is achievable through the application of the best available demonstrated control technology processes, operating methods or other alternatives.

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for
EFFLUENT LIMITATIONS GUIDELINES
and
NEW SOURCE PERFORMANCE STANDARDS
CANE SUGAR REFINING SEGMENT OF THE SUGAR PROCESSING INDUSTRY

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ABSTRACT

This document presents the findings of an extensive study of the cane sugar refining industry for the purpose of recommending Effluent Limitations Guidelines, Federal Standards of Performance, and Pretreatment Standards for the Industry for the purpose of implementing Sections 304, 306, and 307 of the "Act."

Effluent Limitations Guidelines contained herein set forth the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available (BPCTCA) and the degree of effluent reduction attainable through the application of the Best Available Technology Economically Achievable (BATEA) which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The Standards of Performance for new sources (NSPS) contained herein set forth the degree of effluent reduction which is achievable through the application of the Best Available Demonstrated Control Technology, Processes, Operating Methods, or other alternatives.

The cane sugar refining segment of the sugar processing industry has been divided into two subcategories: liquid cane sugar refining and crystalline cane sugar refining. The proposed limitations for all three levels of technology as set forth above establish the requirements for discharge to navigable waters (see Table 1).

Supportive data and rationale for development of the Effluent Limitations Guidelines and Standards of Performance are contained in this document. The remaining segments of the sugar processing industry not contained within this report are raw cane sugar processing and beet sugar processing. Raw cane sugar processing is being studied at this time and is to be presented at a later date. Beet sugar processing has been previously studied and is the subject of a separate report entitled - Beet Sugar Processing Segment of the Sugar Processing Industry.

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SECTION I

CONCLUSIONS

For the purpose of developing Effluent Limitations Guidelines and New Source Performance Standards, the cane sugar refining segment of the sugar processing industry has been divided into two subcategories: (1) liquid cane sugar refining, and (2) crystalline cane sugar refining. The main criterea for subcategorization of the cane sugar refining segment include differences in the manufacturing process employed which result in different waste water loadings.

Factors such as age and size of facilities, nature of water supply, raw material quality, and process variation were considered and found to further substantiate the subcategorization as stated.

It was determined that three refineries are currently achieving no discharge of pollutants to navigable waters by means of land retention. Two refineries discharge all process wastes to municipal treatment systems, and ten other refineries discharge all wastes except barometric condenser cooling water to municipal systems. The majority of the remaining fourteen refineries partially treat their wastes.

It is estimated that the total industry cost of achieving the Best Practicable Control Technology Currently Available (BPCTCA) and the Best Available Technology Economically Achievable (BATEA) are $5,910,000 and $15,000,000 respectively.

The remainder of the cane sugar processing industry, namely the raw cane sugar processing segment, will be studied in a separate effort and a report is to be presented at a later date.

SECTION II
RECOMMENDATIONS

It is recommended that the following effluent limitations be applied as the Best Practicable Control Technology Currently Available (BPCTCA) which must be achieved by existing point sources by July 1, 1977; the Best Available Technology Economically Achievable (BATEA) which must be achieved by existing point sources by July 1, 1983; and the Standards of Performance for new sources (NSPS):

TABLE 1

RECOMMENDED EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

BPCTCA - Crystalline Cane Sugar Refining Subcategory

(a) Any crystalline cane sugar refinery discharging both barometric condenser cooling water and other process waters should be required to meet the following limitations. The BOD_5 limitation is determined by the addition of the net BOD_5 attributed to the barometric condenser cooling water to that amount of BOD_5 attributed to the treated process water. The TSS limitation is that amount of TSS attributed to the treated process water. Where the barometric condenser cooling water and process water streams are mixed and impossible to measure separately prior to discharge, the values should be considered net.

Effluent Characteristic		Effluent Limitations	
		Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
	(Metric units)	kg/kkg of melt	
BOD_5		1.19	0.43
TSS		0.27	0.09
pH		Within the range 6.0 to 9.0.	
	(English units)	lb/ton of melt	
BOD_5		2.38	0.86
TSS		0.54	0.18
pH		Within the range 6.0 to 9.0.	

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TABLE 1

RECOMMENDED EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE
(Continued)

(b) Any crystalline cane sugar refinery discharging barometric condenser cooling water only should be required to achieve the following net limitations:

Effluent Characteristic		Effluent Limitations	
		Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
	(Metric units)	kg/kkg of melt	
BOD5		1.02	0.34
	(English units)	lb/ton of melt	
BOD5		2.04	0.68

BATEA - Crystalline Cane Sugar Refining Subcategory

Effluent Characteristic		Effluent Limitations	
		Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
	(Metric units)	kg/kkg of melt	
BOD5		0.18	0.09
TSS		0.11	0.035
pH		Within the range 6.0 to 9.0.	
	(English units)	lb/ton of melt	
BOD5		0.36	0.18
TSS		0.21	0.07
pH		Within the range 6.0 to 9.0.	

TABLE 1

RECOMMENDED EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE
(Continued)

NSPS - Crystalline Cane Sugar Refining Subcategory

Effluent Characteristic		Effluent Limitations	
		Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
	(Metric units)	kg/kkg of melt	
BOD_5		0.18	0.09
TSS		0.11	0.035
pH		Within the range 6.0 to 9.0.	
	(English units)	lb/ton of melt	
BOD_5		0.36	0.18
TSS		0.21	0.07
pH		Within the range 6.0 to 9.0.	

TABLE 1

RECOMMENDED EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE
(Continued)

BPCTCA - Liquid Cane Sugar Refining Subcategory

(a) Any liquid cane sugar refinery discharging both barometric condenser cooling water and other process waters should be required to meet the following limitations. The BOD_5 limitation is determined by the addition of the net BOD_5 attributed to the barometric condenser cooling water to that amount of BOD_5 attributed to the treated process water. The TSS limitation is that amount of TSS attributed to the treated process water. Where the barometric condenser cooling water and process water streams are mixed and impossible to measure separately prior to discharge, the values should be considered net.

Effluent Characteristic		Effluent Limitations	
		Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
	(Metric units)	kg/kkg of melt	
BOD_5		0.78	0.32
TSS		0.50	0.17
pH		Within the range 6.0 to 9.0.	
	(English units)	lb/ton of melt	
BOD_5		1.56	0.63
TSS		0.99	0.33
pH		Within the range 6.0 to 9.0.	

TABLE 1

RECOMMENDED EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE
(Continued)

(b) Any liquid cane sugar refinery discharging barometric condenser cooling water only should be required to meet the following net limitations:

Effluent Characteristic		Effluent Limitations	
		Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
	(Metric units)	kg/kkg of melt	
BOD$_5$		0.45	0.15
	(English units)	lb/ton of melt	
BOD$_5$		0.90	0.30

BATEA - Liquid Cane Sugar Refining Subcategory

Effluent Characteristic		Effluent Limitations	
		Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
	(Metric units)	kg/kkg of melt	
BOD$_5$		0.30	0.15
TSS		0.09	0.03
pH		Within the range 6.0 to 9.0.	
	(English units)	lb/ton of melt	
BOD$_5$		0.60	0.30
TSS		0.18	0.06
pH		Within the range 6.0 to 9.0.	

TABLE 1

RECOMMENDED EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE
(Continued)

NSPS - Liquid Cane Sugar Refining Subcategory

Effluent Characteristic		Effluent Limitations	
		Maximum for any one day	Average of daily values for thirty consecutive days shall not exceed
	(Metric units)	kg/kkg of melt	
BOD_5		0.30	0.15
TSS		0.09	0.03
pH		Within the range 6.0 to 9.0.	
	(English units)	lb/ton of melt	
BOD_5		0.60	0.30
TSS		0.18	0.06
pH		Within the range 6.0 to 9.0.	

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress towards the national goal of eliminating the discharge of all pollutants, and which reflect the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish within one year of the enactment of the Act regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods, and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the cane sugar refining segment of the sugar processing source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973, (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the cane sugar refining segment of the sugar processing source which was included within the list published January 16, 1973.

SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

The effluent limitations and standards of performance recommended in this report were developed in the following manner.

General information was obtained on all plants and detailed information was collected for 28 (97%) of the 29 domestic cane sugar refineries identified as currently in operation (see Table 2). The sources and types of information consisted of:

a) Applications to the Corps of Engineers for Permits to Discharge under the Refuse Act Permit Program (RAPP) which were obtained for 24 refineries provided data on the characteristics of intake and effluent waters, water usages, wastewater treatment and control practices employed, daily production, and raw materials used.

b) A questionnaire previously submitted to segments of the industry (17 refineries) by the United States Cane Sugar Refiners' Association.

c) On-site inspections of 19 refineries which provided information on process diagrams and related water usage, water management practices, and control and treatment practices.

d) A sampling of four refineries to verify the accumulated data.

e) Other sources of information including personal and telephone interviews and meetings with regional EPA personnel, industry personnel, and consultants; State Permit Applications; internal data supplied by industry; and a review and evaluation of the available literature.

The reviews, analyses, and evaluations were coordinated and applied to the following:

a) An identification of distinguishing features that could potentially provide a basis for subcategorization of the industry. These features included raw material quality, age and size of the refinery, nature of water supply, process employed, and others, discussed in detail in Section IV of this report.

b) A determination of the water usage and waste water characteristics for each subcategory, discussed in Section V, including the volume of water used, the sources of pollution in the plant, and the type and quantity of constituents in the waste waters.

c) An identification of those waste water constituents, discussed in Section VI, which are characteristic of the industry and were determined to be pollutants subject to effluent limitations guidelines and standards of performance.

d) An identification of the control and treatment technologies presently employed or capable of being employed by the re-

TABLE 2

SOURCE OF DATA

Refinery	Type	Location	Size-kkg/day (Average Melt)	Visit	Sample	Data
Amstar	C	Baltimore, Md.	2350	No	No	1,2,4
Amstar	C	Boston, Mass.	900	Yes	No	1,2,3,4
Amstar	C	Brooklyn, N.Y.	1900	Yes	Yes	1,2,3,4,5
Amstar	C	Chalmette, La.	2800	No	No	1,2,4
Amstar	C	Philadelphia, Pa.	1900	No	No	1,2,4
J. Aron	C	Supreme, La.	680	No	No	1,4
C&H	C	Aiea, Hawaii	170	No	No	1,4
C&H	C	Crockett, Ca.	3175	Yes	No	1,3,4
Colonial	C	Gramercy, La.	1350	No	No	1,4
Evercane	C	Clewiston, Fla.	360	Yes	No	3
Glades County	C	Moore Haven, Fla.	420	No	No	3
Godchaux	C	Reserve, La.	1540	No	No	--
Guanica	C	Ensenada, P.R.	200	Yes	No	1,3
Iqualdad	C	Mayaguez, P.R.	630	No	No	1
Imperial	C	Sugarland, Texas	1350	Yes	No	1,2,3,4
Mercedita	C	Ponce, P.R.	545	Yes	No	1,3
National	C	Philadelphia	1900	No	No	1,3,4
Revere	C	Charlestown, Mass.	1090	Yes	No	3
Roig	C	Yabucoa, P.R.	360	Yes	No	1,3
Savannah Foods	C	Port Wentworth, Ga.	1700	Yes	Yes	1,2,3,4,5
South Coast	C	Mathews, La.	635	No	No	1,4
Southdown	C	Houma, La.	635	Yes	No	1,2,3,4
CPC	C-L	Yonkers, N.Y.	1650	No	No	1,2,3,4
SuCrest	C-L	Brooklyn, N.Y.	750	Yes	No	1,2,3
Florida Sugar	L	Belle Glade, Fla.	350	Yes	No	1,3,4
Industrial	L	St. Louis, Mo.	275	Yes	No	1,3,4
Pepsico	L	Long Island, N.Y.	725	Yes	Yes	1,3,5
Ponce Candy	L	Ponce, P.R.	55	Yes	No	1,3
SuCrest	L	Chicago, Ill.	775	Yes	Yes	3,5

C—Crystalline Refinery
L—Liquid Refinery
C-L—Combination Crystalline-Liquid Refinery
1 Corps of Engineers Application
2 Prior Analyses
3 Interview of Plant Personnel
4 Questionnaire
5 Verification Sampling

fining industry, discussed in Section VII, including the effluent level attainable and associated treatment efficiency related to each technology.

e) An evaluation of the cost associated with the application of each control and treatment technology, discussed in Section VIII.

The results of this analysis indicated that three refineries are currently achieving no discharge of pollutants to navigable waters by means of land retention, two refineries discharge all process wastes to municipal treatment systems, and ten other refineries discharge all wastes except barometric condenser cooling water to municipal systems. The majority of the remaining fourteen refineries partially treat or partially retain waste waters.

BACKGROUND OF THE CANE SUGAR INDUSTRY

The earliest recorded production of sugarcane was in Southeast Asia three thousand years ago. Sugarcane was introduced into Europe in the eleventh century, and by the thirteenth century the crystallization of sugar from cane juice was being practiced throughout the Eastern Hemisphere.

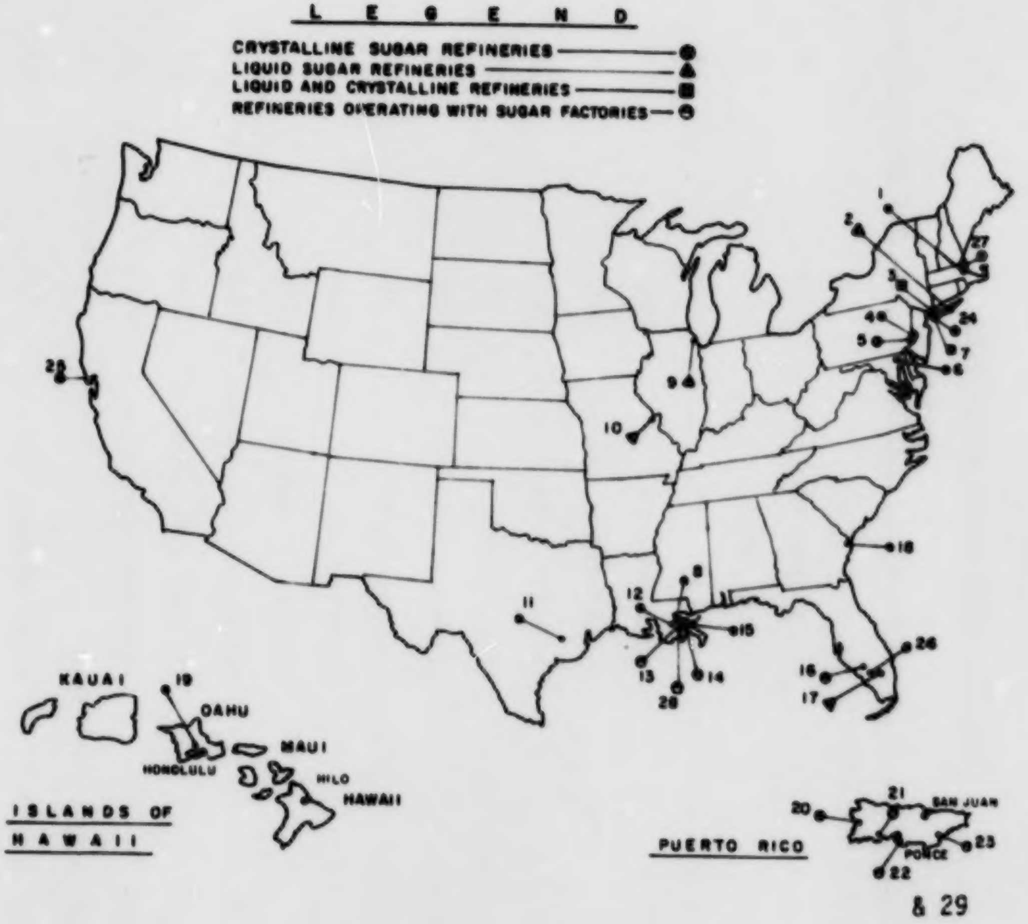
The origin of sugarcane in the Western World was with the second voyage of Columbus in 1493. Commercial cane sugar production began in the United States in the late eighteenth and early nineteenth centuries. The growth of the industry experienced considerable instability until the Federal Sugar Act of 1936 (amended in 1971) provided protective tariffs, a quota system, and price control.

DEFINITION OF THE INDUSTRY

Cane sugar refineries produce either a white crystalline or a clear liquid sugar from unrefined raw sugar which is purchased from domestic or foreign factories. Molasses is produced as a by-product and is sold as animal feed, for the making of alcohol, as a source of certain organic chemicals (ethyl and butyl alcoholols, and acetic and citric acids), and for other uses.

Due to the fact that raw sugar is more economically transported than is refined sugar (raw sugar is not considered to be a foodstuff and thus can be shipped in bulk without extensive sanitary safeguards), refineries are generally located in urbanized retail market areas as shown in Figure 1 and Table 3. The refinery located in Aiea, Hawaii, produces sugar primarily for island consumption. The refinery at Crockett, California, services the West Coast market and receives its raw material primarily from the Hawaiian sugar factories.

In some cases, refineries can be located near both factories and retail markets as can be observed in south Florida, New Orleans, and Hawaii.


LEGEND
CRYSTALLINE SUGAR REFINERIES ●
LIQUID SUGAR REFINERIES ▲
LIQUID AND CRYSTALLINE REFINERIES ■
REFINERIES OPERATING WITH SUGAR FACTORIES ⊖
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KAUAI
19
OAHU
HONOLULU
MAUI
HILO
HAWAII
ISLANDS OF HAWAII
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21
SAN JUAN
23
PONCE
22
PUERTO RICO
& 29

FIGURE 1

AMERICAN CANE SUGAR REFINERIES

TABLE 3

AMERICAN CANE SUGAR REFINERIES

Refinery	Location	Normal Melt kkg/day)	Map No.
[Crystalline Refineries (14)]			
Amstar	Baltimore, Md.	2350	6
Amstar	Boston, Mass.	900	1
Amstar	Brooklyn, N.Y.	1900	24
Amstar	Chalmette, La.	2800	15
Amstar	Philadelphia, Penn.	1900	4
California & Hawaiian	Crockett, Calif.	3175	25
California & Hawaiian	Aiea, Hawaii	170	19
Colonial (Borden)	Gramercy, La.	1350	12
Evercane (Savannah Foods)	Clewiston, Fla.	360	26
Godchaux	Reserve, La.	1540	8
Imperial	Sugarland, Texas	1350	11
National	Philadelphia, Penn.	1900	5
Revere	Charlestown, Mass.	1090	27
Savannah Foods	Port Wentworth, Ga.	1700	18
[Liquid Sugar Refineries (5)]			
Florida Sugar (Borden)	Belle Glade, Fla.	350	17
Industrial (Borden)	St. Louis, Mo.	275	10
Pepsico	Long Island, N.Y.	725	2
Ponce Candy	Ponce, P.R.	55	29
SuCrest	Chicago, Ill.	775	9

TABLE 3 (Continued)

AMERICAN CANE SUGAR REFINERIES

Refinery	Location	Normal Melt (kkg/day)	Map No.
[Liquid-Crystalline Refineries (2)]			
CPC	Yonkers, N.Y.	1650	3
SuCrest	Brooklyn, N.Y.	750	7
[Refineries Operating with Sugar Factories (8)]			
Glades County	Moore Haven, Fla.	420	16
Guanica	Ensenada, P.R.	200	21
Igualdad	Mayaguez, P.R.	630	20
J. Aron & Company	Supreme, La.	680	13
Mercedita	Ponce, P.R.	545	22
Roig	Yabucoa, P.R.	360	23
South Coast	Mathews, La.	635	14
Southdown	Houma, La.	635	28

The refineries in Puerto Rico, all of which operate in conjunction with raw sugar factories, serve the Puerto Rican domestic market.

The 24 refineries in the continental United States and Hawaii are owned by fifteen private corporations or cooperatives. Four of the refineries in Puerto Rico are operated by the Puerto Rican government. Those organizations operating more than one refinery are listed in Table 4.

TABLE 4

MULTIPLE OWNERSHIP OF SUGAR REFINERIES

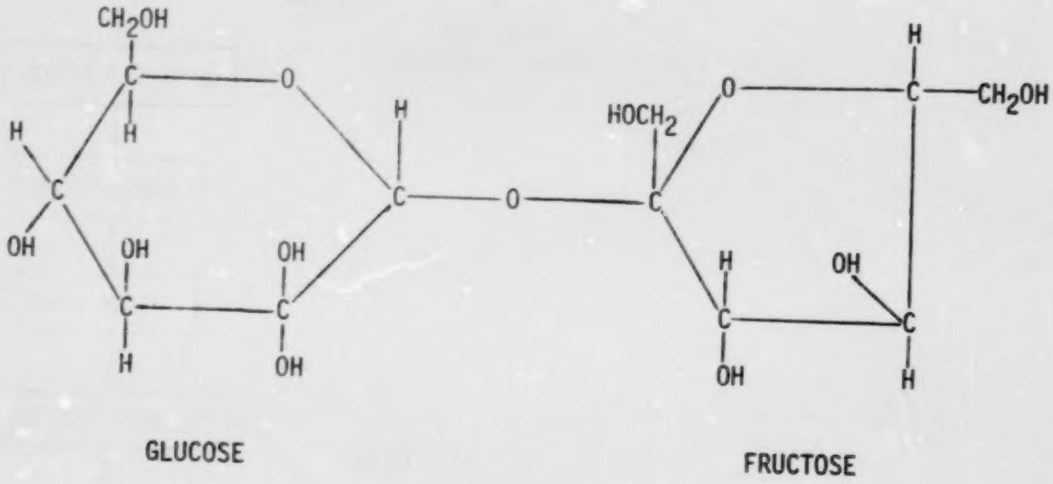
Owner	Headquarters	Number of Refineries
Amstar	New York, N.Y.	5
California & Hawaiian	San Francisco, California	2
Borden	Columbus, Ohio	3
Savannah Foods	Savannah, Georgia	2
SuCrest	New York, New York	2

PROCESS DESCRIPTION - CANE SUGAR REFINERIES

The raw material for cane sugar refining is the raw, crystalline sugar produced by the cane sugar factories. Raw sugar consists primarily of crystals of sucrose ($C_{12}H_{22}O_{11}$) with small percentages of dextrose (glucose) and levulose (fructose), both with formulas of ($C_6H_{12}O_6$), as shown in Figure 2, and various impurities which may include bagasse particles, organics, inorganic salts, and microorganisms. Raw sugar crystals contain a film of molasses, the thickness of which varies with the purity of sugar, and in which the non-sucrose components are concentrated.

The raw sugar processed by the American refineries may be of domestic or foreign origin, and the production as well as the importation of raw sugar is closely governed by U.S.D.A. quota. From a refining process viewpoint, there is little difference in raw sugar related to its source other than the amount of impurities present.

A cane sugar refinery receives raw sugar in bulk form by truck, rail, barge, and/or ship, and stores it for periods up to several months in large warehouses. As required by the refining process, the raw sugar is conveyed from storage through continuous weighing to the magma mingler, the first step in sugar refining. Figure 3 presents a simplified process diagram of cane sugar refining.



CH2OH
H
H
OH
OH
H
OH
OH
H
O
O
HOCH2
O
H
CH2OH
H
OH
OH
H
GLUCOSE
FRUCTOSE

FIGURE 2

SUCROSE OR α-D-GLUCOPYRANOSYL--β-D-FRUCTOFURANOSIDE

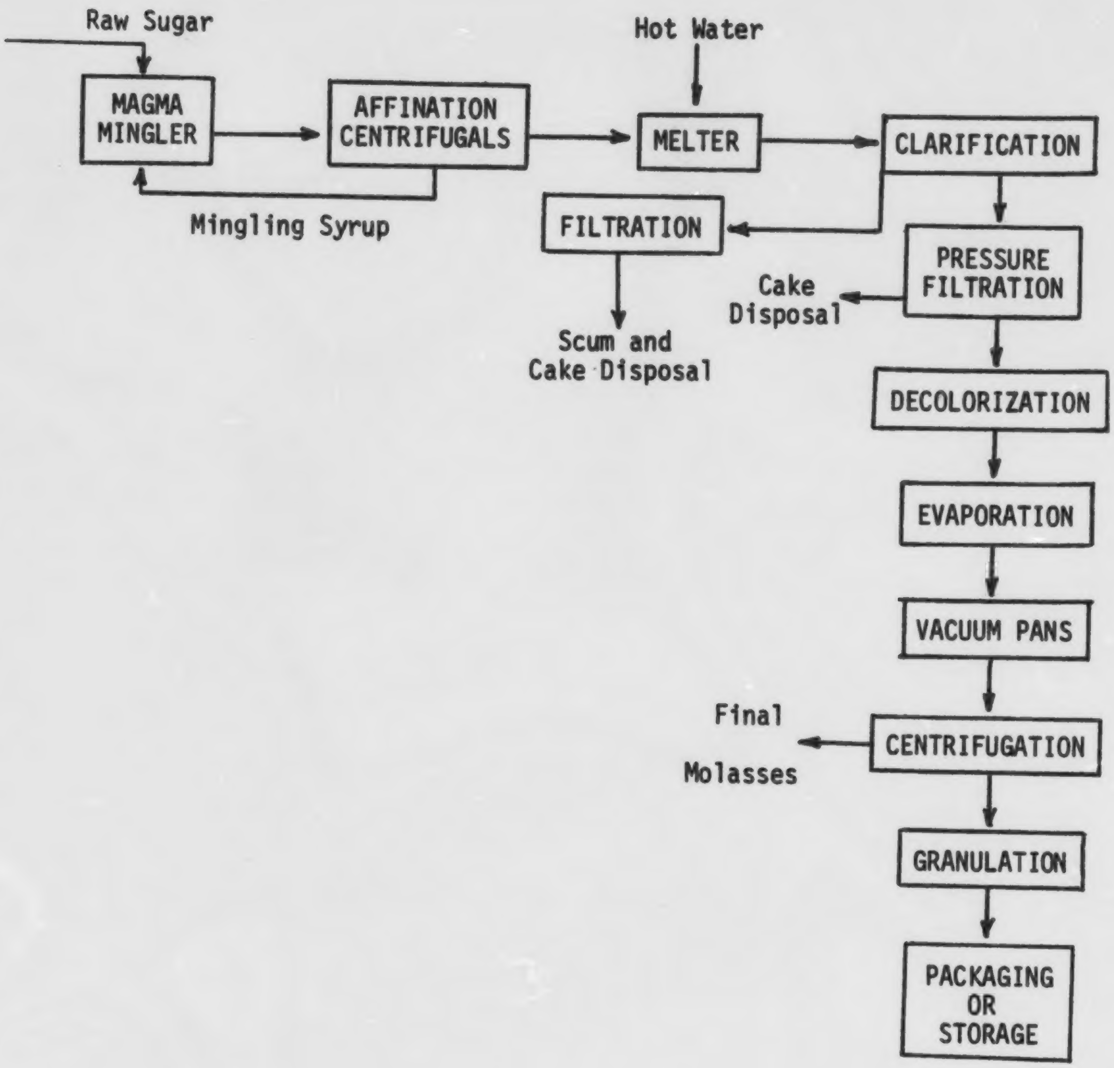

Raw Sugar
MAGMA MINGLER
AFFINATION CENTRIFUGALS
Mingling Syrup
Hot Water
MELTER
CLARIFICATION
FILTRATION
Scum and Cake Disposal
PRESSURE FILTRATION
Cake Disposal
DECOLORIZATION
EVAPORATION
VACUUM PANS
CENTRIFUGATION
Final Molasses
GRANULATION
PACKAGING OR STORAGE

FIGURE 3

SIMPLIFIED PROCESS DIAGRAM FOR CANE SUGAR REFINING

Sugar refining may be broadly defined as the removal of most of the molasses film and associated impurities from the surface of the raw sugar crystals. The crystalline raw sugar is washed to remove part of the molasses film, then placed into solution, taken through various purification steps, and finally recrystallized. While the process is simple in scope, a detailed discussion could fill many volumes. This discussion will be necessarily of a limited nature. Furthermore, processes may vary in detail considerably from refinery to refinery, particularly in decolorization methods where the media may be bone char, granular activated carbon, powdered activated carbon, vegetable carbon, ion-exchange or other materials. The predominate media in the United States, however, is bone char. Figure 4 presents a process flow diagram of bone char refining and Figure 5 is a schematic of carbon refining.

Affination and Melting

The first step in the refining process is affination which begins with mingling, or placing the raw crystals into a syrup solution. The main source of the mingling syrup is the affination centrifugals. Either the recycled syrup is heated in order to aid in loosening the molasses film, or the resulting magma is heated in a revolving mixer. The magma is fed into centrifugals, which separate the syrup and molasses from the sugar. Hot water is then added to provide a washing action. The washed sugar is discharged into a melter which also contains about one-half of the sugar's weight in water. High-test sweet waters and remelt syrups may also be added. Steam heat and mechanical mixing are supplied to the melter. Melt liquor leaves the melter at a constant density of about 65° Brix and a temperature of about 66° Centigrade (150° Fahrenheit).

The liquor is subjected to coarse screening and, in many cases, fine screening to remove coarse materials such as sand and scale. These relatively small amounts of impurities are normally discarded as solid waste.

Clarification (Defecation)

The screened melt liquor still contains fine suspended and colloidal matter which are removed in clarification. Clarification may involve coagulation and either flotation clarifiers or pressure filtration. The most common chemical defecants are phosphoric acid, carbon dioxide, and lime. The result of this treatment is neutralization of organic acids and formation of a tri-calcium phosphate precipitate which entrains much of the colloidal and other suspended matter in the liquor. Carbonation produces a calcium carbonate precipitate. Inert filter aids, most commonly diatomaceous earth, may be used alone or in conjunction with phosphoric acid.

Clarification systems that remove the colloidal and suspended precipitate by air flotation are called frothing clarifiers and are based simply on the principle of rising air bubbles trapping the precipitate and forming a scum on the liquid surface. Pressure

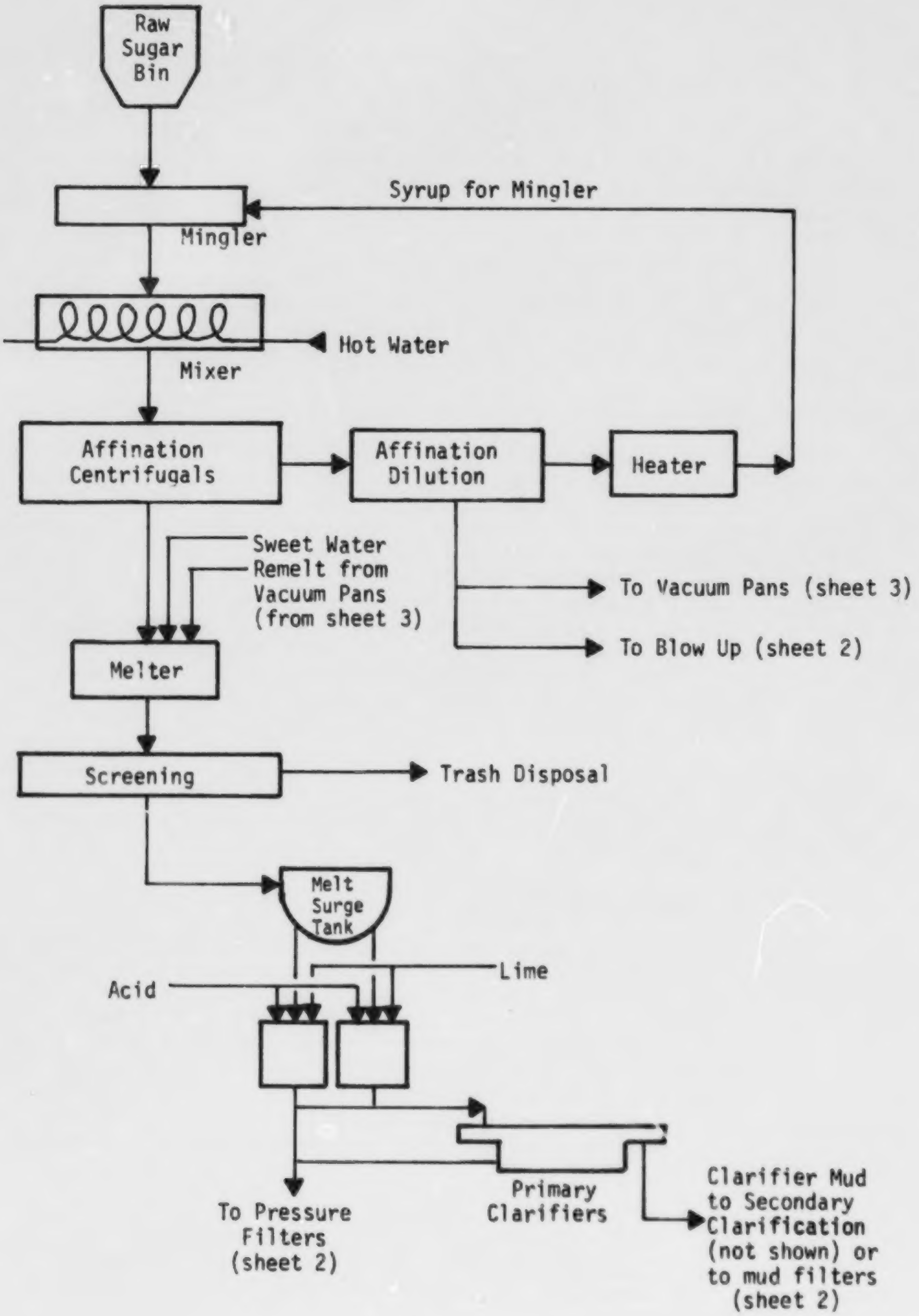

Raw Sugar Bin
Syrup for Mingler
Mingler
Hot Water
Mixer
Affination Centrifugals
Affination Dilution
Heater
Sweet Water
Remelt from Vacuum Pans (from sheet 3)
To Vacuum Pans (sheet 3)
To Blow Up (sheet 2)
Melter
Screening
Trash Disposal
Melt Surge Tank
Lime
Acid
To Pressure Filters (sheet 2)
Primary Clarifiers
Clarifier Mud to Secondary Clarification (not shown) or to mud filters (sheet 2)

FIGURE 4

TYPICAL BONE CHAR REFINERY **Sheet 1 of 3**

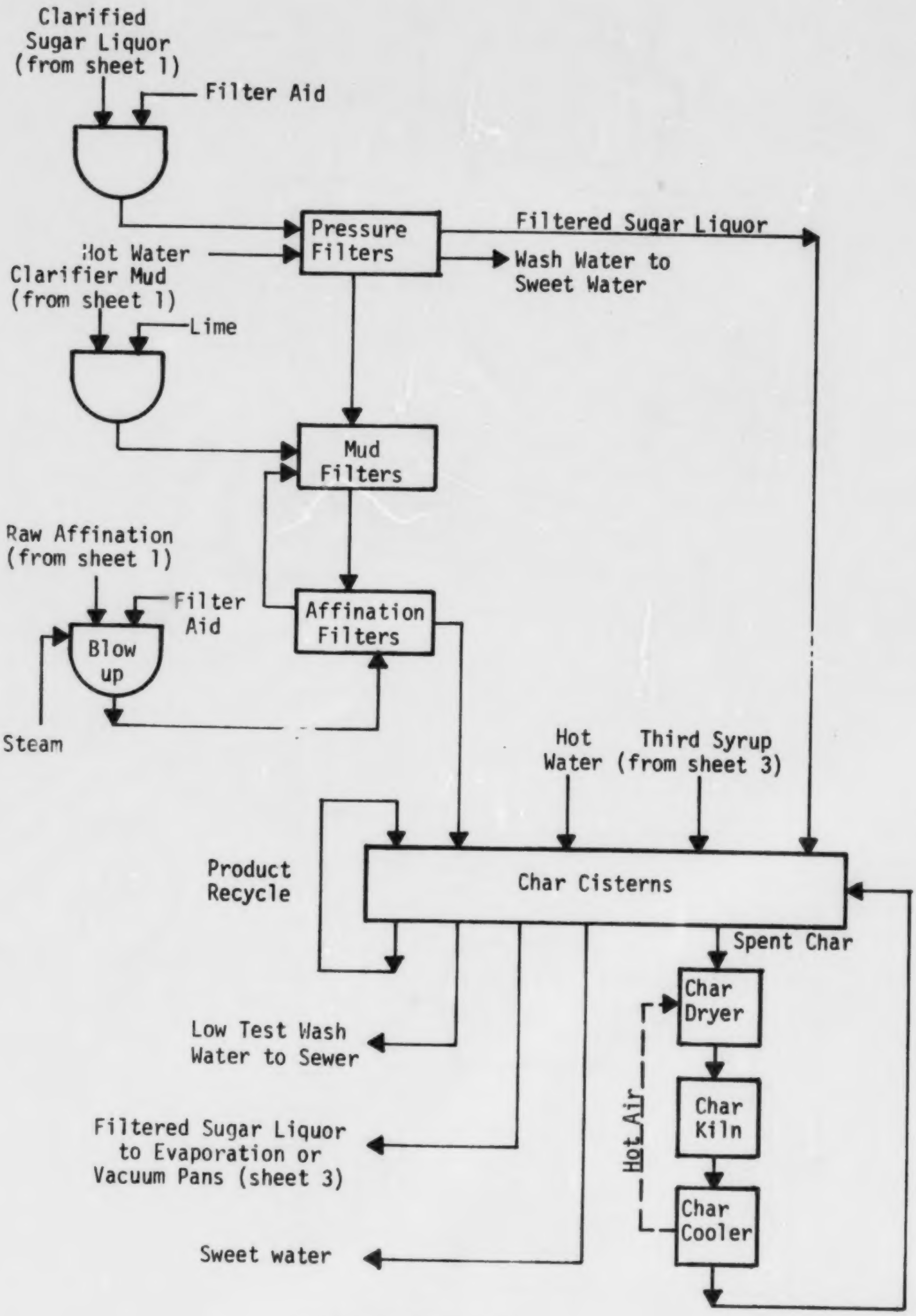

Clarified Sugar Liquor (from sheet 1)
Filter Aid
Pressure Filters
Filtered Sugar Liquor
Hot Water
Wash Water to Sweet Water
Clarifier Mud (from sheet 1)
Lime
Mud Filters
Raw Affination (from sheet 1)
Filter Aid
Blow up
Affination Filters
Steam
Hot Water
Third Syrup (from sheet 3)
Product Recycle
Char Cisterns
Spent Char
Char Dryer
Hot Air
Char Kiln
Char Cooler
Low Test Wash Water to Sewer
Filtered Sugar Liquor to Evaporation or Vacuum Pans (sheet 3)
Sweet water

FIGURE 4 (CONTINUED)

TYPICAL BONE CHAR REFINERY

Sheet 2 of 3

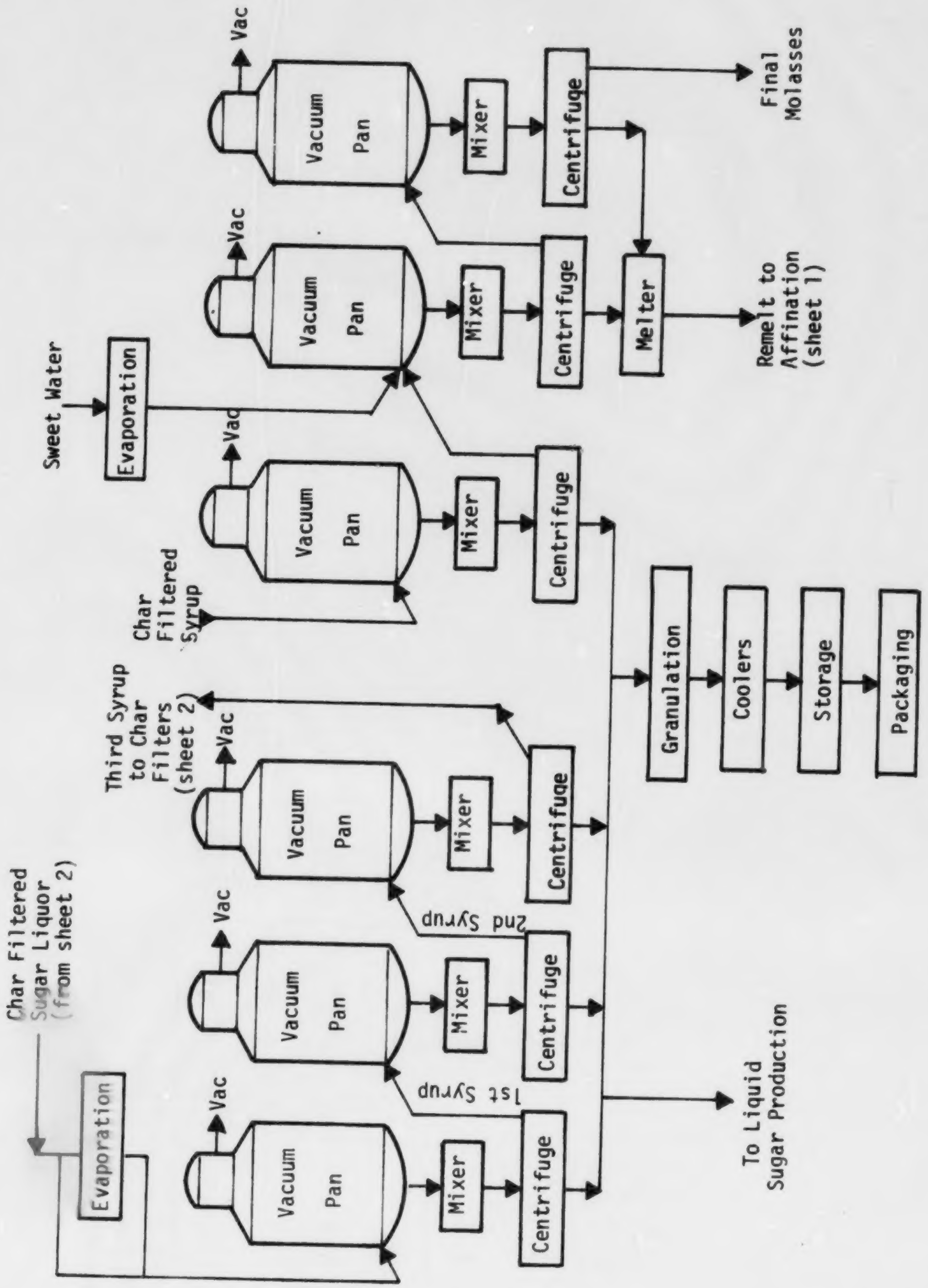

Char Filtered
Sugar Liquor
(from sheet 2)
Evaporation
Vac
Vacuum
Pan
Mixer
Centrifuge
1st Syrup
Vac
Vacuum
Pan
Mixer
Centrifuge
2nd Syrup
Third Syrup
to Char
Filters
(sheet 2)
Vac
Vacuum
Pan
Mixer
Centrifuge
To Liquid
Sugar Production
Char
Filtered
Syrup
Vac
Vacuum
Pan
Mixer
Centrifuge
Granulation
Coolers
Storage
Packaging
Sweet Water
Evaporation
Vac
Vacuum
Pan
Mixer
Centrifuge
Melter
Remelt to
Affination
(sheet 1)
Vac
Vacuum
Pan
Mixer
Centrifuge
Final
Molasses

FIGURE 4 (CONTINUED)

TYPICAL BONE CHAR REFINERY

Sheet 3 of 3

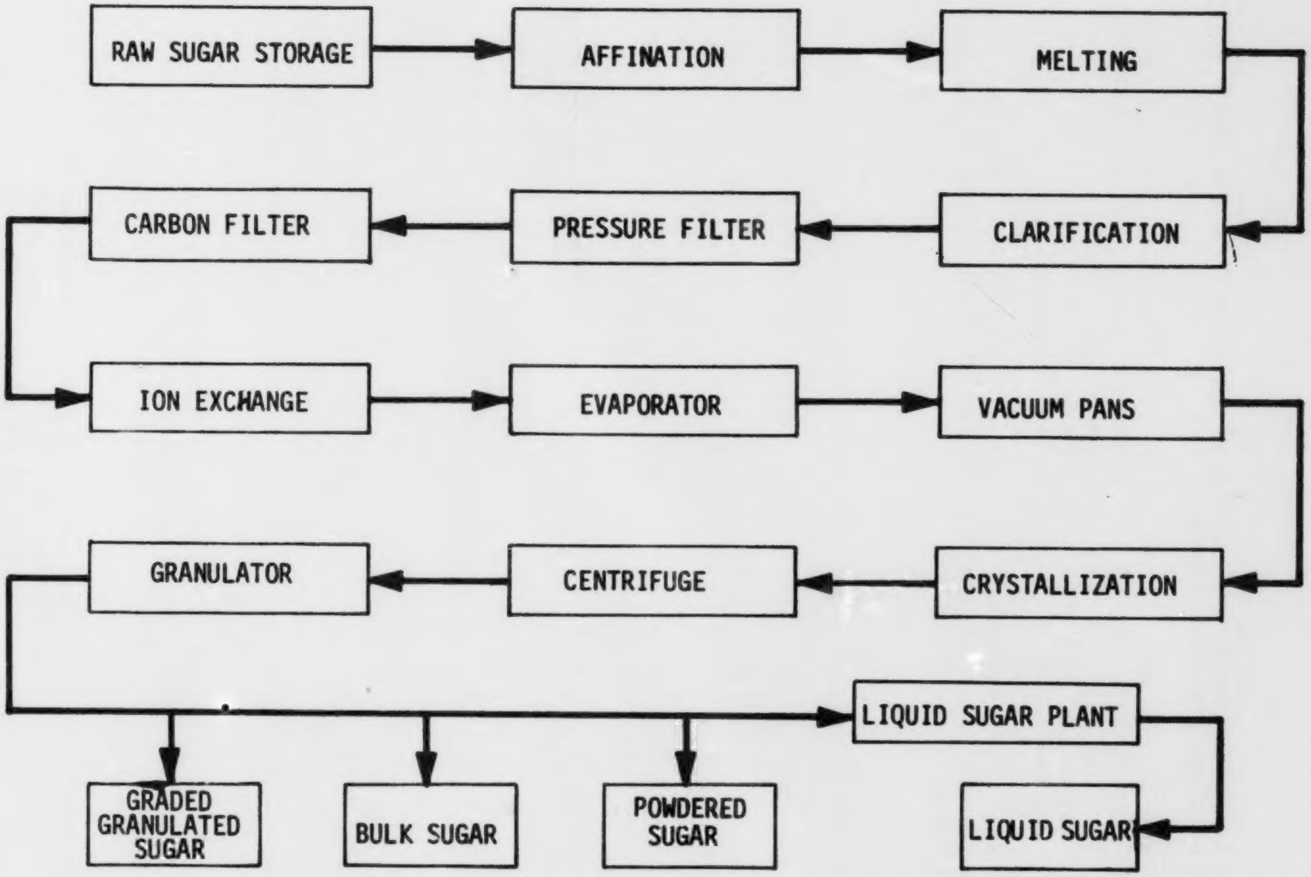

RAW SUGAR STORAGE
AFFINATION
MELTING
CARBON FILTER
PRESSURE FILTER
CLARIFICATION
ION EXCHANGE
EVAPORATOR
VACUUM PANS
GRANULATOR
CENTRIFUGE
CRYSTALLIZATION
LIQUID SUGAR PLANT
GRADED GRANULATED SUGAR
BULK SUGAR
POWDERED SUGAR
LIQUID SUGAR

FIGURE 5

TYPICAL CARBON REFINERY

filtration commonly takes place in a cloth or leaf-type filter with cake removal by means of high pressure sprays.

The muds, scums, and filter muds produced in clarification contain significant sugar concentrations which must be recovered. Frothing clarifier scums, particularly tri-calcium phosphate scums, are often sent to a second clarifier and the resulting scum is filtered on rotary vacuum drums with the addition of filter aid. The press cake is usually handled in a dry form and taken to landfill but may be slurried. High-test sluicings may be dewatered in rotary vacuum filters and the resulting sweetwater added to affination syrups and the dewatered cake used as filter aid for filtration.

Decolorization

After affination and clarification, the sugar liquor still contains impurities and color that require physical adsorption for removal. As previously stated, most large crystalline refineries use fixed bed bone char cisterns (also called filters), although in more than 50 years there have been no new refineries equipped with them. An individual cistern is commonly three meters (ten feet) in diameter and six meters (20 feet) deep and holds approximately 36 metric tons (40 tons) of bone char and 20,800 liters (5,500 gallons) of sugar liquor. There are generally 30 cisterns per million kilograms of daily melt.

Sugar liquor passes in parallel through each cistern in a downward direction and undergoes adsorption of the color bodies and ions. From 90 to 99 percent of color is removed, with the higher removal occurring at the beginning of the cycle. Divalent cations and anions and polyvalent organic ions are effectively removed, as are phosphate and bicarbonate. Monovalent ions are not removed.

After some period of operation, the decoloration ability of the char decreases to an unacceptable level and the char must be washed and regenerated by heat in kilns or char house furnaces. The sugar liquor in the cistern is displaced with a piston effect by hot water. The water effluent is a low purity sweet water and is taken to evaporation for sugar recovery. The total amount of sweet water produced is usually about one-half of the cistern's volume.

After the purity of the water effluent has degraded to a point where further sugar recovery is considered uneconomical, it is released as a waste water stream. The amount of wash water used may be governed either by time or by ash content.

After the last of the wash water has drained from the char cistern, the char is discharged from the cisterns, dried by hot air, and regenerated in kilns. The kilns provide a temperature of about 550° Centigrade and a controlled amount of air. Under these conditions any organic residue is destroyed and the buffering and decolorizing capacity of the char is renewed.

The operation of a granular carbon refinery is in many ways similar to that of a char refinery, but there are at the same time significant differences. Granular carbon adsorbs minimal ash and produces considerably more sweet water. The only waste water normally associated with the decolorization step in the process is water used for transporting the carbon. Transport water can be reused as transport water, but must be discharged periodically due to bacterial growth. Most granular carbon refineries discharge transport water once or twice a week.

Powdered activated carbon is used for decolorization in small refineries and in liquid sugar production. Regeneration of powdered carbon is difficult and it is normally discarded after one or two cycles. However, in 1972, one company announced the successful and economical regeneration of powdered activated carbon.

The clarified liquor is contacted and agitated for about 15 to 20 minutes with a slurry of carbon prepared with water or sugar solution. After that period of time, carbon will not adsorb more coloring matter, but coloring matter already adsorbed can be washed back into the sugar solution. The temperature of treatment is about 82° Centigrade (180° Fahrenheit). After the treatment is completed, about five kilograms (10 pounds) of filter aid per 3,800 liters (1,000 gallons) of sugar liquor is admixed and thoroughly dispersed in the liquor before filtration. The filtration is accomplished in filter aid precoat-type leaf filters. The cycle of each filter unit varies from five to twenty four hours, depending on the filterability and color of the sugar liquor that is being filtered. The decolorized filtrate is checked in a precoat-type leaf filter and then sent to the double-effect evaporators for concentration prior to crystallization. The total filter aid consumption is about 0.4 to 0.5 percent based on refined sugar output. The filter cake containing the filter aid, carbon, and impurities is sent in slurry form to the clarification scum tank, and all this mixture is filtered in a dry discharge type pressure filter (either plate and frame or leaf type); all solids are discarded, after sweetening off, in dry cake or slurry form in a suitable disposal area.

Ion-exchange resins are used to a limited extent in sugar refining for demineralization (deashing) or further color removal. They are used most extensively in carbon and liquid sugar refineries. Refinery liquors are percolated through a cation-exchanger which adsorbs alkaline salts from the liquor and leaves it highly acidic. Then the liquor is percolated through an anion-exchanger which removes the free acid and converts the sugar liquor to a neutral state. This double percolation can be avoided by using cationic and anionic resins mixed together in a single-bed cistern. The operation of ion-exchange beds in refineries is not unlike that of many industrial applications in that they are regenerated in place with sodium chloride, sulfuric acid, or other chemicals depending on the type of resin. The cost and disposal of chemicals needed for regeneration of ion-exchangers has precluded its application for the entire refining process.

Evaporation

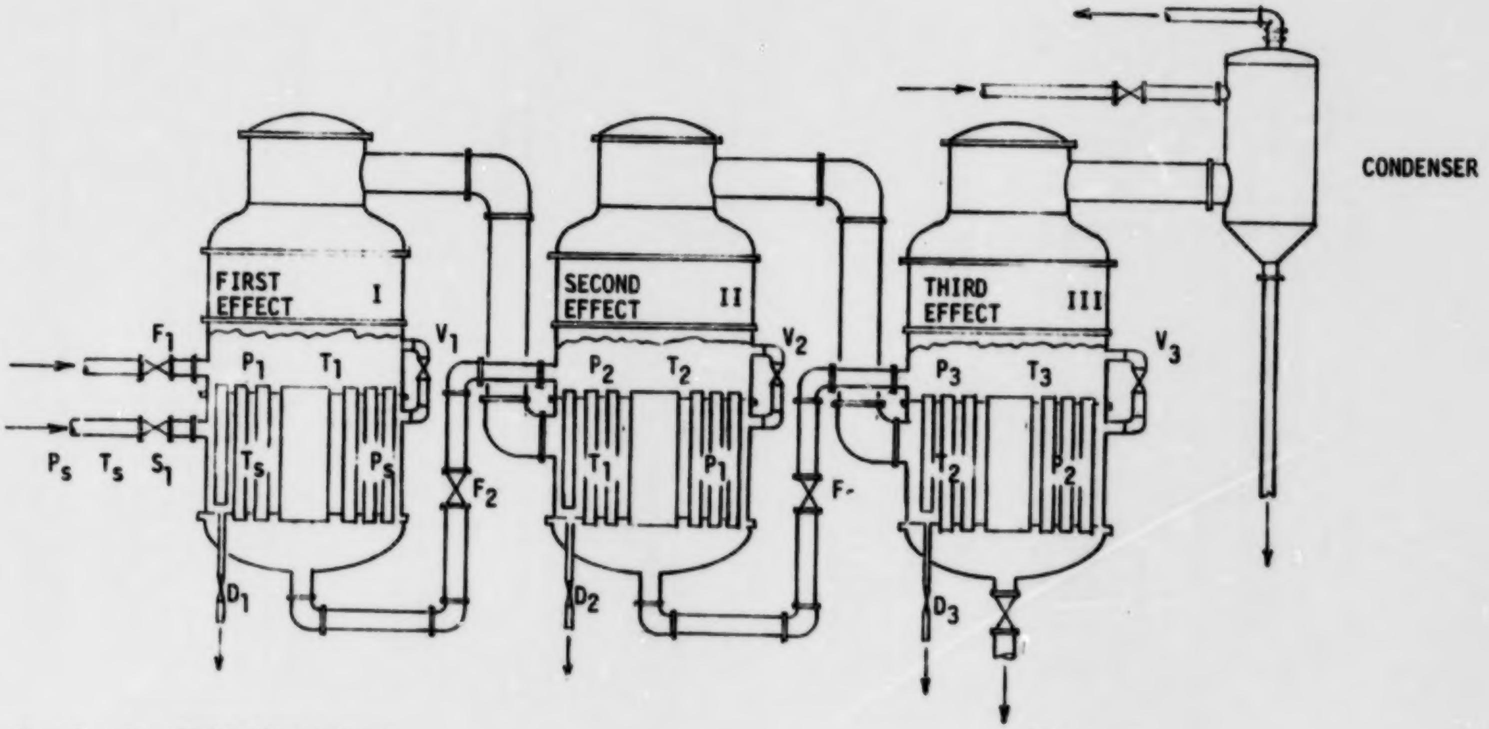
No matter what method of decolorization is used, the final steps of recrystallizing and granulating are essentially the same in all refineries. The first step in recrystallization is the concentration of the decolorized sugar liquor and sweet waters in continuous-type evaporators.

An evaporator is a closed vessel heated by steam and placed under a vacuum. The basic principle is that the juice enters the evaporator at a temperature higher than its boiling temperature under the reduced pressure, or is heated to that temperature. The result is flash evaporation and the principle allows evaporators to be operated in a series of several units. This practice is called multiple-effect evaporation, with each evaporator being an "effect", and is illustrated in Figure 6. In general, the vacuum in each effect is created by the condensation of the vapors from that effect in the subsequent effect. The heat of vaporization of the juice in each effect is supplied by the vapors from the previous effect, with the exception of the first and last effects. The first effect normally has live steam or exhaust steam resulting from power production provided to it, and the last effect has a vacuum caused by the condensation of its vapors in the condenser. The temperature and pressure of each effect is, therefore, lower than the preceding effect.

The cane sugar refining industry commonly uses double or triple-effect evaporation with the short tube or calandria type of evaporator (as illustrated), although the Lillie film evaporator is used in some installations.

Condensation of the last effect vapors may be provided by one of several condenser designs, but all operate on the principle of relatively cold water passing through a cylindrical vessel, contacting the hot vapors, and condensing them. The resulting hot water leaves through a long vertical pipe called a barometric leg. Air is removed from the system by a vacuum pump or steam ejector. The condenser cooling water, or barometric leg water, at a flow rate of perhaps 76,000 cubic meters per day (20 million gallons) in a large refinery, is the largest volume of water used in a cane sugar refinery. It is often untreated river or sea water and is unsuitable for reuse in other processes in sugar refining although some refineries use better quality water which is recycled after cooling in a cooling tower or spray pond, and then reused in other processes.

A problem common to the sugar refiner in his attempt to prevent sugar loss and to the environmentalist in his attempt to prevent pollution is the entrainment of sugar in the vapors from the evaporators and vacuum pans. The condensed steam from the first effect has not come into direct contact with the sugar solution and is essentially pure water. It is usually used as feed water for the steam boilers as is the condensate from the second effect. The condensates from the other effects experience relatively little sugar entrainment and are used as


F
F_1
P_s
T_s
S_1
FIRST EFFECT
I
P_1
T_1
T_s
P_s
V_1
F_2
D_1
SECOND EFFECT
II
P_2
T_2
T_1
P_1
V_2
F-
D_2
THIRD EFFECT
III
P_3
T_3
T_2
P_2
V_3
D_3
CONDENSER

D_1, D_2, D_3, CONDENSATE VALVES
F_1, F_2, F_3, FEED VALVES
S_1, STEAM VALVE
V_1, V_2, V_3, VENT VALVES
P_s, P_1, P_2, P_3, PRESSURES
T_s, T_1, T_2, T_3, TEMPERATURES

FIGURE 6

TRIPLE EFFECT EVAPORATION

process water; however, in some cases "excess" condensate may be discharged as a waste stream. The major problem, then, is with the vapor from the last effect which tends to have greater entrainment than the other effects. Due to its mixing with the condenser water, the resultant volume is too large for reuse in the process. However, condenser water may be recirculated. If recirculated, the warm water from the condensers of evaporators and vacuum pans is cooled in cooling towers or spray ponds and recycled. Only a fraction of the volume goes to the stabilization ponds as blowdown from the cooling tower or spray pond. This volume is a function of the dissolved solids content of the water being used as barometric condenser cooling water. One would not recycle brackish water because of the high concentration of dissolved solids. With good quality water, this blowdown can be less than one percent.

Various methods of reducing entrainment are used in the industry, but most are based on either the principle of centrifugal action or that of direct impact; i.e., changing the direction of vapor flow so that liquid droplets may veer away from the vapor, be impinged on a surface, and ultimately be returned to the liquid body, or allowing the vapor to come into direct contact with a wet surface. Schematics of various methods commonly used are shown in Figure 7.

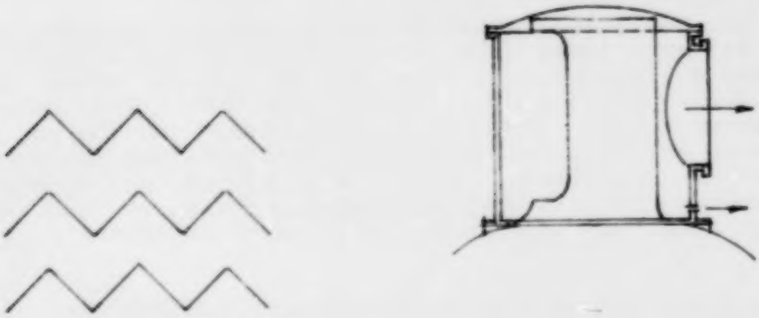
The distance between the liquid level in the evaporator and the top of the cylindrical portion of the body is called the vapor belt. This distance has a great effect on the degree of entrainment because the further the vapor has to rise the greater the opportunity for liquid droplets to fall out. Most evaporator vapor belts in refineries range from 3.7 to 4.9 meters (12 to 16 feet) or about 2.0 to 2.5 times the length of the tubes.

Refineries monitor sucrose concentrations in condensate and condenser water in order to avoid sugar contamination in boiler feed waters and sugar loss in condenser water. The frequency of monitoring may vary from continuous (auto analyzers) to hourly, daily, or weekly. The methods of analysis for sucrose most commonly used are the alphanaphthol and resorcinol tests. Both methods are based on color change resulting from the reaction of the test reagent with sucrose.

Crystallization

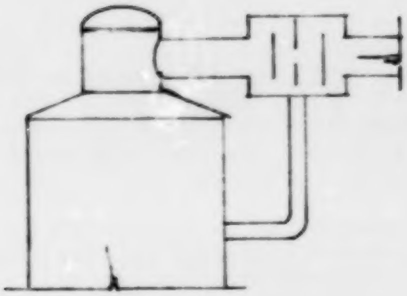
After concentration in evaporators, in the case of crystalline refineries, the sugar liquor and sweet waters are crystallized in single-effect, batch type evaporators called vacuum pans. Several pans are used exclusively for commercial granulated sugar and the resulting syrups are boiled in other pans, as shown in Figure 4. Calandria pans are commonly used and are similar to the calandria evaporator described above except that the pans have larger diameters and shorter tubes in order to handle the more concentrated liquid.

In order for sugar crystals to grow in a vacuum pan, the sugar solution must be supersaturated. There are three phases of supersaturation in

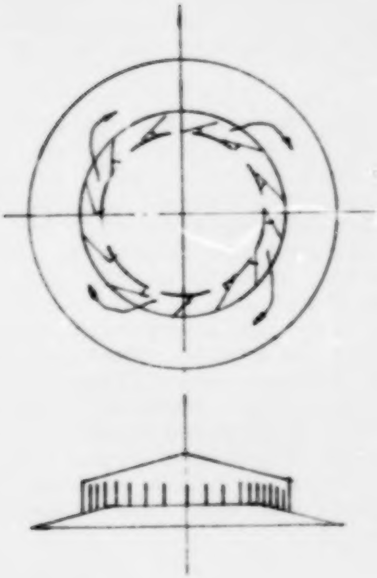


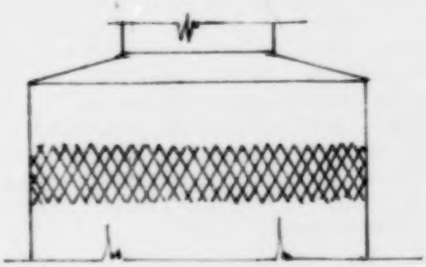
(A) Zig-Zag Baffle

(B) Catch All



(D) In-Line Baffle Box





(C) Cyclone Separator

(E) Demister

FIGURE 7

DEVICES TO REDUCE ENTRAINMENT

sugar boiling; the metastable phase in which existing crystals grow but new crystals do not form, the intermediate phase in which existing crystals grow and new crystals do form, and the labile phase in which new crystals form spontaneously without the presence of others. The formation of new or "false" crystals is undesirable and the pan must be maintained in that narrow range of sucrose concentration and temperature which provides the metastable phase and allows the growth of seed crystals. Automatic controls such as level, pressure, and viscosity instrumentation for pan operation are used extensively in sugar refining.

Since vacuum pans are essentially single-effect evaporators, each pan must have a vacuum source and a condenser, as described above for evaporators. Sugar entrainment is a potential problem, particularly during start-ups or upsets, and various catchalls, centrifugal separators, or baffle arrangements are used along with sucrose monitoring (see Figure 7). In some cases a small surface condenser is inserted between the pan and the barometric condenser to act as a heat exchanger in order to heat process water. This also serves to reduce sucrose entrainment.

After the formation of crystals in the pans, the massecuite content of the pan--called a strike--is discharged into a mixer where it is gently agitated, and then into high speed centrifugals where the crystals are separated from the syrup. The crystals remaining in the centrifugals are washed with hot water to remove remaining syrup, and the crystalline sugar is discharged and sent to a combined dryer-cooler or to a dryer followed by a cooler.

There are normally four straight refinery massecuites boiled in the vacuum pans: filtered and evaporated first liquor and three remelt strikes derived from affination syrup, refinery run-off, soft sugar run-offs, and excess sweet water. The first refinery strike is boiled from first liquor, the second is boiled from first strike run-off, the third refinery strike is boiled from second run-off and the fourth strike from third run-off. The procedure of boiling second, third, and fourth refinery massecuites is the same as for the first one. In a refinery where only white sugar is produced, the last refinery strike run-off (fourth) can be used in affination as a mingling syrup. Some refineries use it to produce "soft sugars". It can be diluted and filtered through bone char or granulated adsorbents, or treated with powdered activated carbon and used again in boiling. The sugar recovered from the remelt strikes is used for the production of additional refined sugar and well exhausted refinery blackstrap molasses. From 10 to 15 percent of the original solids in the melt are recycled through the remelt (or recovery) stations.

Finishing

The dryer or granulator is usually a horizontal, rotating drum 1.5 to 2.4 meters (five to eight feet) in diameter and 7.6 to 11 meters (25 to 35 feet) long which receives steam heated air along with the sugar crystals. It may consist of one or more drums in parallel. The granulators remove most of the one percent moisture content to 0.02 percent or less. In addition, the dryers serve to separate the crystals from one another. After drying, the sugar goes to coolers, which are similar drums without the heating elements.

Any lumps remaining in the sugar are then removed by fine screening. Screening also accomplishes crystal size grading.

Both the granulating and screening processes produce considerable amounts of dust. Wet dust collectors are commonly used to collect this dust and the resulting sugar solution is collected as sweet water.

The finished crystalline sugar is transported to conditioning silos and then ultimately to packaging or bulk shipment. In the larger granulated sugar refineries it is not uncommon to produce liquid sugar by melting granulated sugars and then decolorizing the solution with powdered activated carbon; the resulting solution is then filtered and cooled before being sent to storage as liquid sucrose. It may also be inverted to either 100 percent, 50 percent or any other degree of inversion and stored separately from liquid sucrose in stainless steel clad tanks provided with ultra-violet lamps and air circulation filters for sterilization purposes.

Liquid Sugar Production

As noted in Table 3, there are four refineries in the United States that produce liquid sugar exclusively as a final product and two that produce large portions of liquid as well as crystalline sugar. Most of the remaining twenty-two produce some liquid sugar by melting granulated sugar.

As shown in Figure 8, the initial refining steps of affination, decolorization, and even evaporation in a liquid sugar refinery are essentially the same as in a crystalline sugar refinery. The primary difference occurs in the fact that liquid sugar refineries do not recrystallize their primary product. While this preempts the necessity of using vacuum pans to effect crystal formation and growth in the case of the primary product, nevertheless, all but two liquid refineries use vacuum pans for the crystallization of remelt sugars, producing molasses as a by-product. The two liquid refineries that do not remelt use a highly pure raw material. The production of liquid sugar is essentially a concentration and decolorization of the melted raw sugar solution. Because crystal formation is not a part of primary liquid sugar production, considerably less condenser water and process steam is required. This results in substantially less water usage to process the same quantity of raw cane sugar into liquid sugar than that required to process it into crystalline sugar. This is further discussed in Section V. After evaporation, the sugar solution is filtered and cooled and then sent to storage as liquid sugar. It may also be inverted to a specific degree and stored separately in stainless steel clad tanks equipped with ultra-violet lamps and air circulation filters to insure

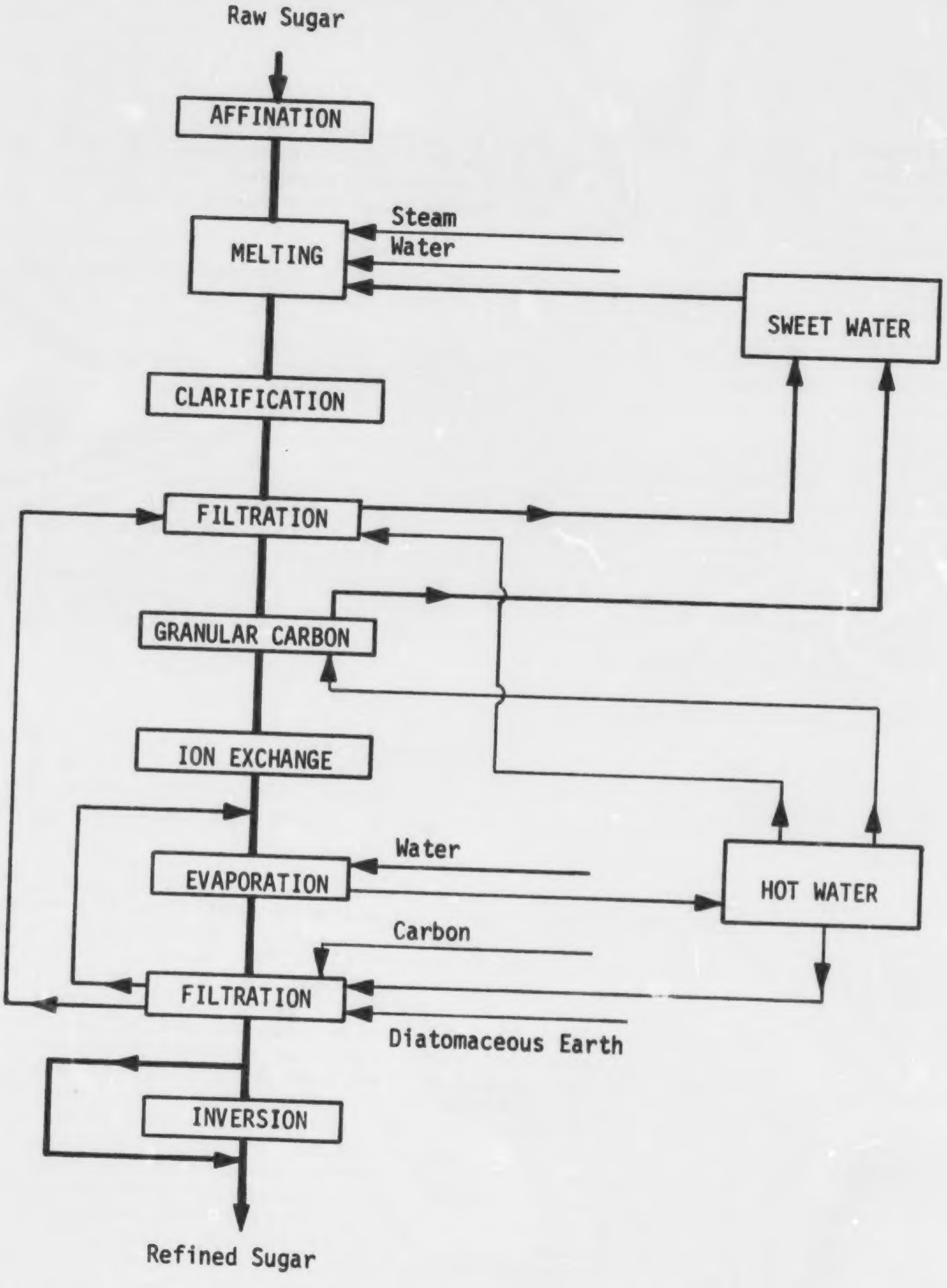

Raw Sugar
AFFINATION
MELTING
Steam
Water
SWEET WATER
CLARIFICATION
FILTRATION
GRANULAR CARBON
ION EXCHANGE
Water
EVAPORATION
HOT WATER
Carbon
FILTRATION
Diatomaceous Earth
INVERSION
Refined Sugar

FIGURE 8

LIQUID SUGAR REFINING

sterilization. The processes of filtration and inversion are the same as those used in the formulation of liquid sugar by the melting of crystalline sugar.

SECTION IV

INDUSTRY CATEGORIZATION

In the development of effluent limitation guidelines and standards of performance for the cane sugar refining industry, it was necessary to determine whether significant differences exist which form a basis for subcategorization of the industry. The objective of industry subcategorization is to subdivide the industry in order that separate effluent limitations and standards be established for such subcategories. Several factors were considered significant with regard to identifying potential subcategories in the cane sugar refining industry. These factors included:

1) Raw material quality
2) Refinery size
3) Refinery age
4) Nature of water supply
5) Land availability
6) Process variation

After consideration of the above factors, the cane sugar refining industry has been divided into two subcategories: liquid cane sugar refining and crystalline cane sugar refining. The justification for this subcategorization is presented below.

Raw Material Quality

All cane sugar refineries process raw sugar as produced by raw sugar factories. An obvious point of inquiry in this regard is the source of raw sugar--namely, imported versus domestic raw sugar. A significant portion of raw sugar refined in the United States is imported from Africa, Latin America, the Phillipine Islands, and Southeast Asia. Depending upon the operation of the factory, and to some extent upon the conditions under which raw sugar is shipped and stored, raw sugar could vary in impurity and moisture content. Investigations revealed that no significant variation in raw sugar quality exists because of specifications imposed by individual refineries.

The exceptions are two liquid refineries which impose higher than normal standards for raw sugar purchases. One refinery purchases raw sugar from selected Louisiana and Central America factories, while the other purchases from selected Florida factories. The high quality of raw sugar allows these two refineries to avoid remelting and preempts the use of vacuum pans (as previously discussed in Section III, Introduction) . Neither of these refineries discharges waste water directly to surface waters. One is located in an urban area and discharges all waste to a municipal sewer; the other has a rural siting and has geographical conditions which allow for total impoundage of all waste waters.

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For the purpose of establishing national effluent limitations and standards, these two refineries are considered to be exceptions to general practices. They are therefore not applicable as examples of best practicable or best available technologies because of the nonavailability of this high-purity raw sugar to the refining industry in general. For this reason, separate subcategorization based on raw material quality is not required.

Refinery Size

As indicated in Section III, cane sugar refineries vary considerably in size. The smallest operation is the Ponce Candy refinery, with a refining capacity of 55 metric tons (60 tons) per day. The California & Hawaiian refinery at Crockett, California, with a refining capacity of 3175 metric tons (3500 tons) per day, claims the distinction of being the world's largest sugar refinery. Other large refineries are located in the urbanized Northeast, in Savannah, Georgia, and in the New Orleans area. The smaller refineries are generally those associated with sugar factories.

It might be expected that larger refineries would have better operation than smaller ones; however, in actual practice this is not always the case. While data are more variable for small refineries, no evidence is available which shows significant differences in process water usage (See Section V). For the above reasons size is not regarded as a technical element for subcategorization. Size is considered to be a factor to be further studied for possible economic impact; for this reason, cost estimates for control and treatment pertaining to typical large and small refineries are included in Section VIII, Cost, Energy, and Non-Water Quality Aspects.

Refinery Age

Cane sugar refineries vary considerably in age of structure; several of the larger refineries currently operating were originally constructed in the decades following the American Civil War, while others were constructed after the Second World War. On a basis of unit operations employed, all refineries have undergone a process of continuous modernization. The age of the walls of a refinery is no indication of the age of the processing equipment within the walls. No definitive subcategorization on the basis of age can be established. This conclusion is further substantiated in that one of the oldest refineries has been determined to be exemplary in terms of inplant controls and practices and raw waste characteristics.

Nature of Water Supply

The quantity and quality of fresh water supplies utilized by refineries were originally considered to be possible elements for industry subcategorization because of potential prohibitive factors that could be encountered in control and treatment. Water used for process or boiler water must be of highest quality; if a high quality source of water is unavailable, a refinery must provide treatment. However, the quality of water used as condenser cooling water is unimportant; it was observed to vary from municipal water to sea water. Typically, refineries use a low quality surface water as barometric condenser cooling water.

The major importance of the gross characteristics of condenser water is that with a high quality intake, the discharge (which essentially has no net pollution except for temperature and entrained sucrose) can be reused in the refining process. Thus a major waste water stream, condenser cooling water, can be significantly reduced or, depending on the relative volumes, virtually eliminated. One refinery accomplishes this by utilizing municipal water as the source for condenser cooling water. It is a liquid refinery which does not use vacuum pans, for reasons discussed above and in Section III, and thus has a relatively low volume of condenser water. More typically, due to the volumes required and based on present practices, refineries utilize available surface waters as condenser cooling water, regardless of quality.

Land Availability

Land availability was originally considered as a possible element for subcategorization because of the potential economic advantages and technical feasibility of waste water treatment and retention by lagooning, land disposal, and impoundage (see Section VII, Control and Treatment Technology). Land availability has been defined as the ownership or potential ownership of land, or the use or potential use of land owned by others with the owner's permission, with such land being of sufficient quantity to provide treatment of waste water by lagooning, land disposal, or impoundage, and with the stipulation that the economic value of the land does not prohibit its use in such manner. For a number of large refineries in urban areas, the nonavailability of land must further be defined as the lack of sufficient space for industrial waste water treatment facilities. However, these refineries presently have access to municipal treatment systems, to which they discharge their process waste water.

It was determined that relatively little of the sugar refining industry has available land. Forty-five percent of the refinery installations may be considered to be rurally located, but these represent only about 25 percent of the industry on a production basis. Land and excavation costs for total impoundage of waste waters make this treatment alternative prohibitive for the industry as a whole. The option exists, however, with a proper choice of site location based on a careful consideration of geographical and climatic conditions, for new sources to utilize the availability of land in eliminating discharge to navigable waters. For the purpose of establishing uniform national effluent limitations guidelines and standards land availability is not regarded as a technical element necessitating subcategorization.

Process Variation

While the production of refined sugar from raw sugar involves similar operational principles in any refinery, in practice considerable process variation can occur. These variations may be caused by the end product desired or by the attitude of refinery management.

The only process variation which produces significant differences with regard to waste water generation is that which produces liquid versus crystalline sugar (discussed previously in Section III). Due to the reduced amount of recrystallization necessary in liquid refining, crystalline refineries discharge almost twice as much water (on a unit basis) as liquid refineries. In terms of BOD_5 loading, liquid refineries produce approximately two times as much BOD_5 (on a unit basis) as crystalline refineries. This will be further discussed in Section V, Water Use and Waste Characterization.

Another process difference which has to be considered as a potential element for subcategorization is the type of decolorization medium used in the production of crystalline sugar--activated carbon versus bone char. As is shown in Section V, no significant differences occur in process water use as a result of utilization of bone char versus activated carbon as the decolorization medium.

Because of significant differences in water usage and waste loadings the cane sugar refining industry has been divided into two subcategories: liquid cane sugar refining and crystalline cane sugar refining. Within the liquid sugar subcategory there are four refineries which produce exclusively liquid sugar and two refineries which produce liquid in addition to crystalline sugar. These refineries account for over twenty percent of total sugar production. The remainder of the twenty-nine refineries produce crystalline sugar as their primary product.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

SPECIFIC WATER USES - CANE SUGAR REFINERIES

Figure 9 shows a schematic diagram of water usage and waste water flows in a typical liquid sugar refinery and Figure 10 presents one for a typical crystalline refinery. The major in-plant water uses include:

- Barometric condenser cooling water
- Filter cake slurry
- Char wash
- Floor wash water
- Carbon slurries
- Boiler makeup
- Truck and car wash
- Affination water
- Ion-exchange regeneration

Water use varies widely among cane sugar refineries due to variations in process, water reuse, and conservation techniques. As shown in Table 5, the amount of fresh water used in refineries varies from 10.5 to 64.2 cubic meters per metric ton (2,520 to 15,400 gallons per ton) of raw sugar melted. The average water usage in liquid sugar refineries is approximately 18.1 cubic meters per metric ton (4,350 gallons per ton), while the average for crystalline refineries is appxoximately 38.2 cubic meters per metric ton (9,160 gallons per ton). Combination crystalline-liquid cane sugar refineries use approximately 35.2 cubic meters per metric ton (8,450 gallons per ton).

Water balances for a liquid and a crystalline refinery are shown in Figures 11 and 12, respectively. Negligible water enters a sugar refinery from raw material. High quality fresh water enters the liquid refinery illustrated at a rate of 1.67 cubic meters per metric ton of raw sugar (400 gallons per ton) and is used for all process purposes other than cooling water. Cooling water is used for the barometric condensers at a rate of 20.9 cubic meters per metric ton (5,000 gallons per ton) of raw sugar melted, and the source of this water is typically the nearest body of surface water. Raw water in the crystalline refinery shown is used at a rate of 45.1 cubic meters per metric ton (10,800 gallons per ton) of raw sugar melted; 3.38 cubic meters (810 gallons) of this is high quality water used for various purposes while 41.7 cubic meters (10,000 gallons) is low quality surface water used as barometric condenser cooling water.

In general, cane sugar refineries are more sophisticated in waste water control techniques than are sugar factories (and more conscious of sugar losses); however, current practices for water reuse are generally limited to recovery of high purity sweetwaters for their sucrose content and reuse of condensates for boiler feed water and other purposes.

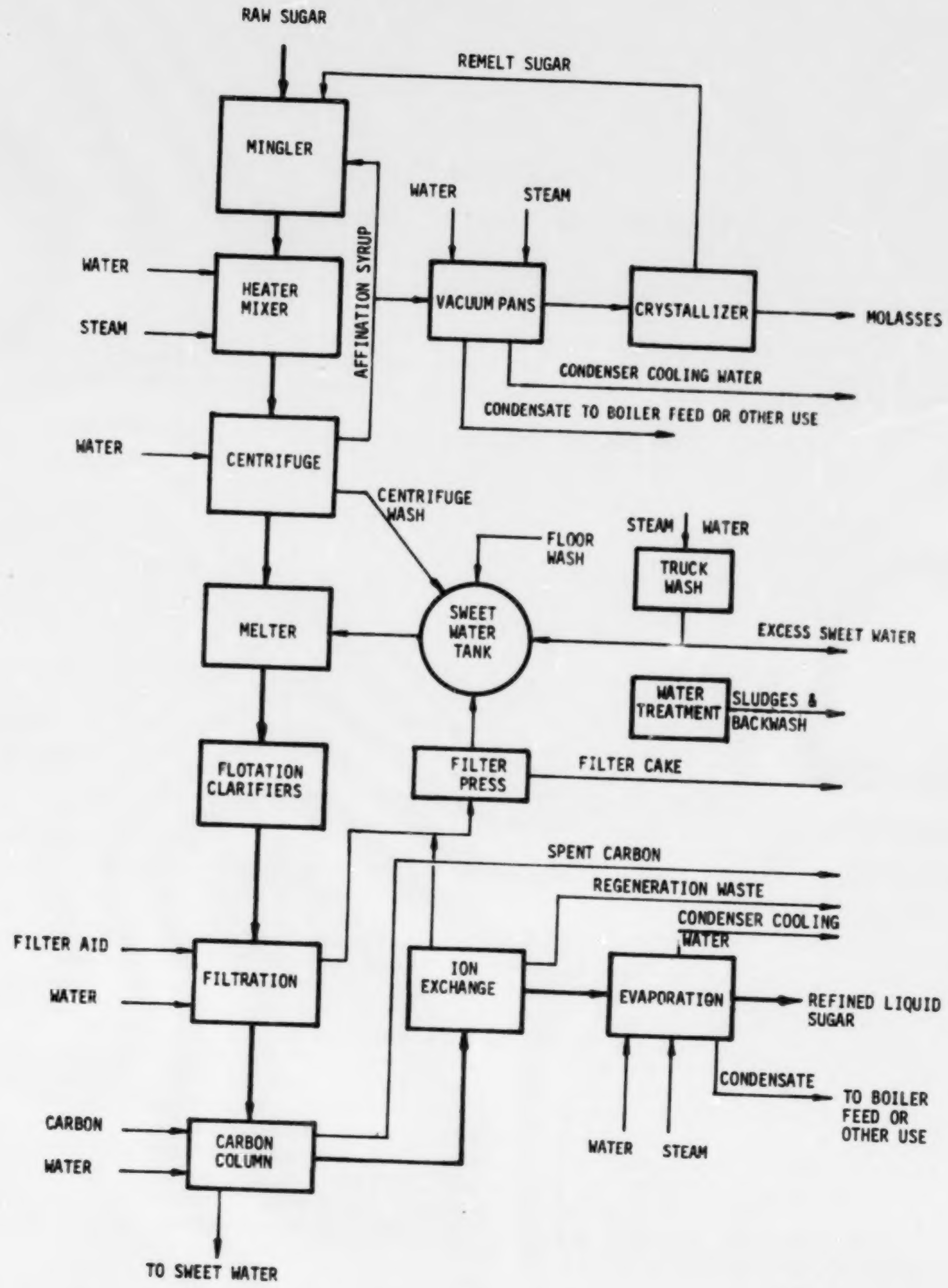

RAW SUGAR
REMELT SUGAR
MINGLER
WATER
STEAM
HEATER MIXER
AFFINATION SYRUP
WATER
STEAM
VACUUM PANS
CRYSTALLIZER
MOLASSES
CONDENSER COOLING WATER
CONDENSATE TO BOILER FEED OR OTHER USE
WATER
CENTRIFUGE
CENTRIFUGE WASH
FLOOR WASH
STEAM
WATER
TRUCK WASH
MELTER
SWEET WATER TANK
EXCESS SWEET WATER
WATER TREATMENT
SLUDGES & BACKWASH
FLOTATION CLARIFIERS
FILTER PRESS
FILTER CAKE
SPENT CARBON
REGENERATION WASTE
CONDENSER COOLING WATER
FILTER AID
WATER
FILTRATION
ION EXCHANGE
EVAPORATION
REFINED LIQUID SUGAR
CONDENSATE
TO BOILER FEED OR OTHER USE
CARBON
WATER
CARBON COLUMN
WATER
STEAM
TO SWEET WATER

FIGURE 9

WASTEWATER FLOW DIAGRAM FOR A LIQUID SUGAR REFINERY

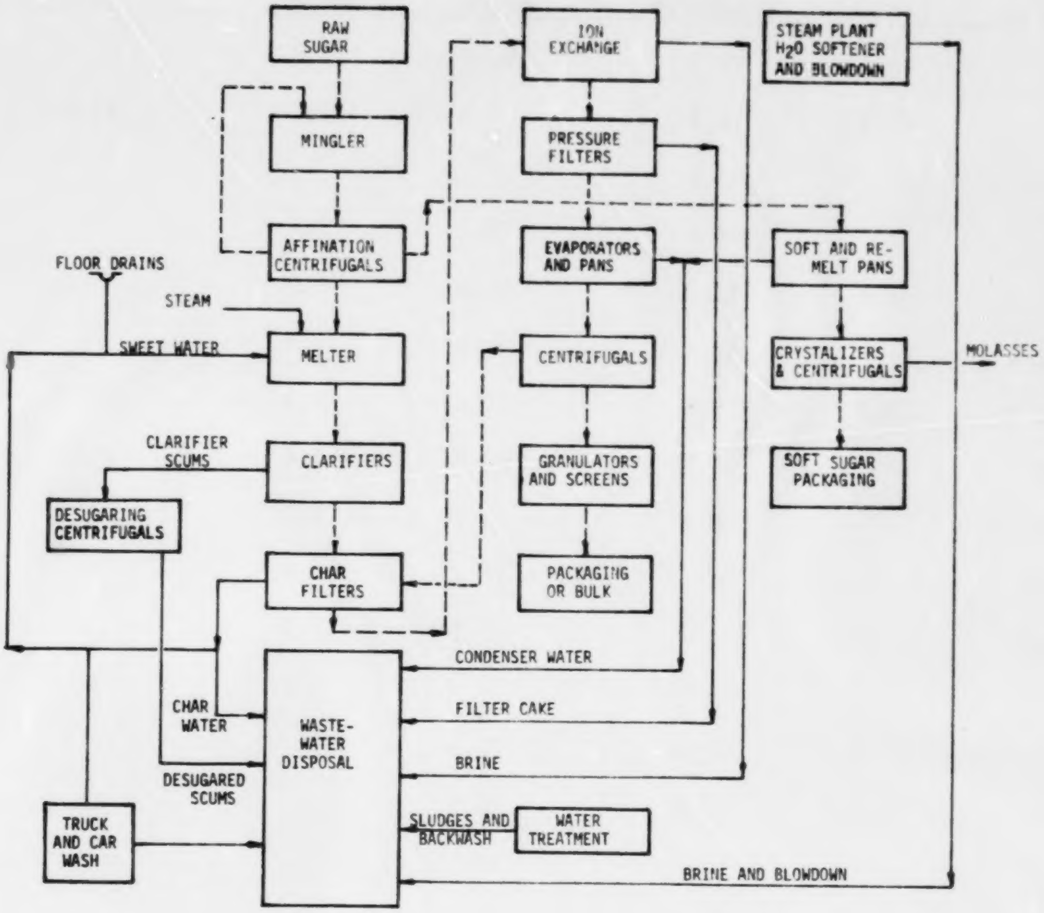

RAW SUGAR
MINGLER
AFFINATION CENTRIFUGALS
FLOOR DRAINS
STEAM
SWEET WATER
MELTER
CLARIFIER SCUMS
CLARIFIERS
DESUGARING CENTRIFUGALS
CHAR FILTERS
CHAR WATER
DESUGARED SCUMS
TRUCK AND CAR WASH
WASTE-WATER DISPOSAL
ION EXCHANGE
PRESSURE FILTERS
EVAPORATORS AND PANS
CENTRIFUGALS
GRANULATORS AND SCREENS
PACKAGING OR BULK
CONDENSER WATER
FILTER CAKE
BRINE
SLUDGES AND BACKWASH
WATER TREATMENT
BRINE AND BLOWDOWN
STEAM PLANT H_2O SOFTENER AND BLOWDOWN
SOFT AND RE-MELT PANS
CRYSTALIZERS & CENTRIFUGALS
MOLASSES
SOFT SUGAR PACKAGING

FIGURE 10

WASTEWATER FLOW DIAGRAM FOR A CRYSTALLINE REFINERY

TABLE 5

UNIT WATER* INTAKE AND WASTE WATER DISCHARGES CANE SUGAR REFINERIES

Refinery	Intake	Discharge	Condenser Water	Process Water	Decolorization Wash
C-1	48.5	48.5	44.9	3.6	
C-2	16.8	16.8	16.1	0.7	0.66
C-3		42.9			
C-4		44.6	43.2	1.4	
C-5	45.2	43.8	42.5	1.3	
C-6		42.4	40.6	1.8	
C-7	25.8	25.8	24.4	1.4	0.54
C-8		64.2	62.8	1.4	0.84
C-9		38.1	34.1	4.0	
C-11		25.0	24.4	0.6	
C-12		63.1	61.7[1]	1.4	
C-14		3.32[2]	23.5	2.7	0.22
L-1	10.5	10.5	8.0		
L-2	16.0	16.0	16.0		
L-3		16.0	14.1	1.9	
L-4		30.0	26.9	3.1	

---

* All values expressed as cubic meters per kkg of melt.

[1] Based on pump capacity, not on actual measured flows.

[2] Has a recycle system for barometric condenser cooling water resulting in a reduction in water discharged.

TABLE 5
(CONTINUED)

UNIT WATER* INTAKE AND WASTE WATER DISCHARGES
CANE SUGAR REFINERIES

Refinery	Intake	Discharge	Condenser Water	Process Water	Decolorization Wash
CL-1		22.5	21.3	1.2	
CL-2	47.9	47.9	47.1	0.8	
CF-1			91.3[3]	1.0	
CF-2			45.0	8.6[4]	
CF-3			68.6[5]	2.2	
CF-4			72.0[6]	1.4	

* All values expressed as cubic meters per kkg of melt.

[3] Based on vacuum pan capacity, not on actual measured flows.

[4] Includes substantial water usage as a result of factory operations (i.e. continuous water spray of bagasse pile). Maximum discharge as a result of refinery operation alone approximated at 3.0 m^3/kkg of melt.

[5] Based on pump capacity, not on actual measured flows.

[6] Based on maximum barometric condenser capacity; a greater than 50% overflow occurs over pumping capacity of 86.9 m^3/kkg of melt making 43.5 m^3/kkg of melt the upper limit of actual barometric condenser cooling water flow.

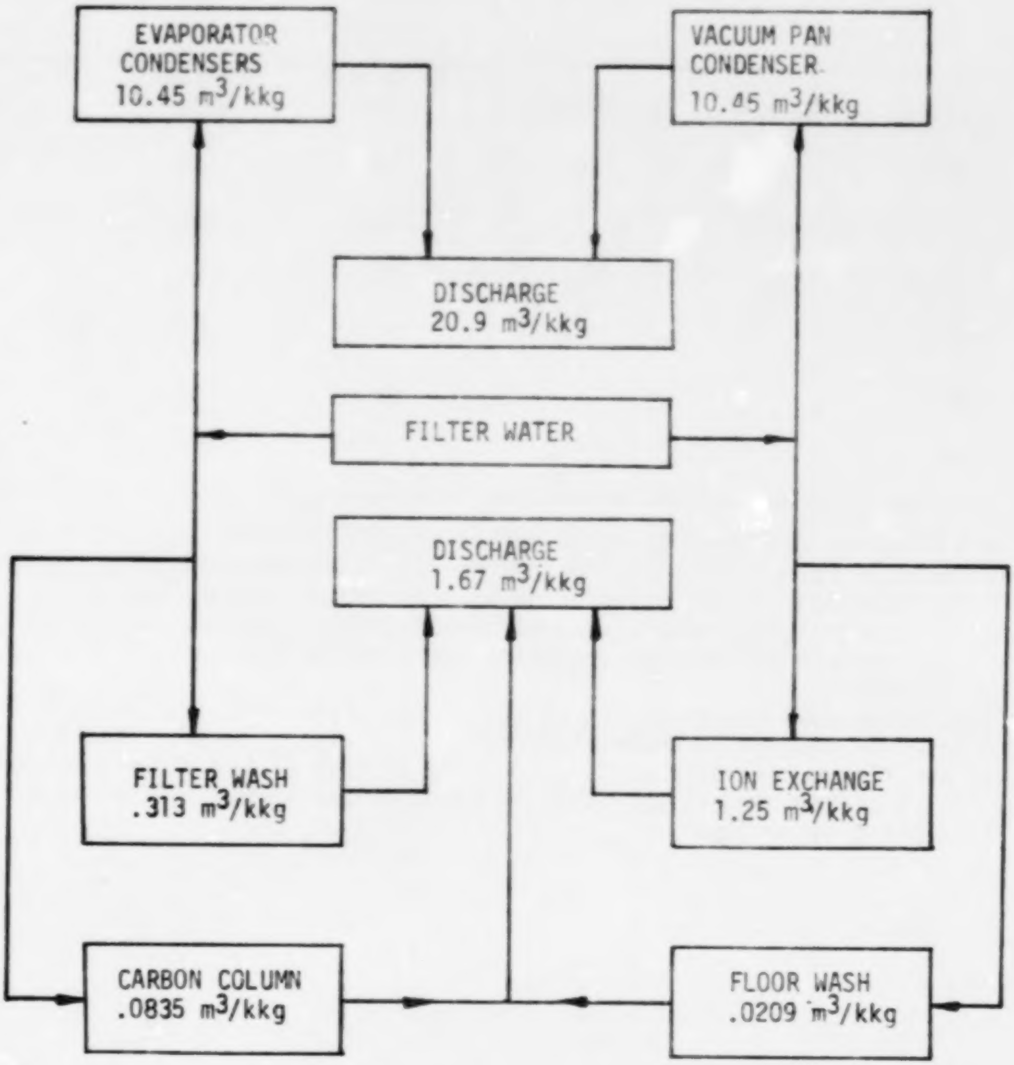
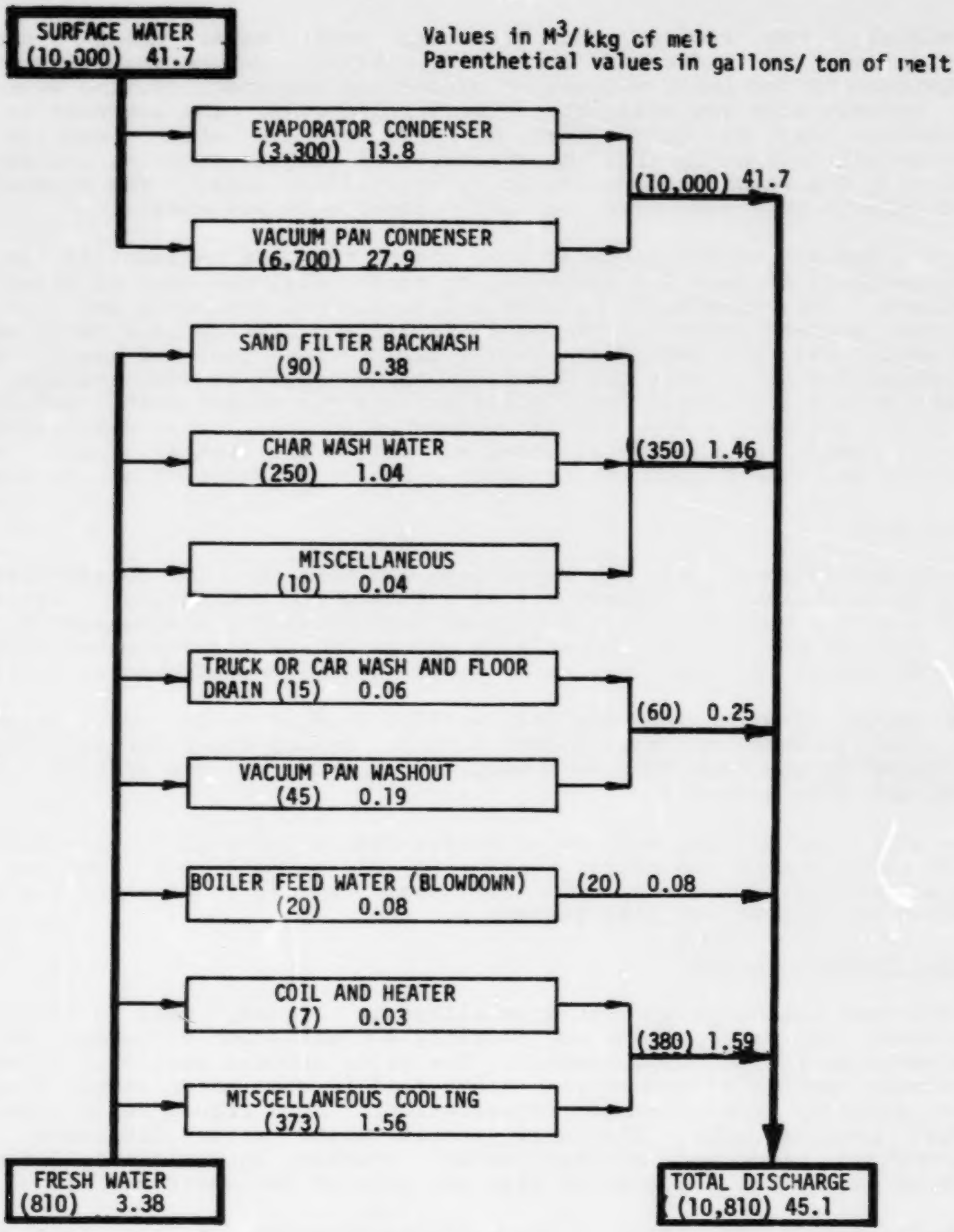

EVAPORATOR CONDENSERS 10.45 m3/kkg
VACUUM PAN CONDENSER 10.45 m3/kkg
DISCHARGE 20.9 m3/kkg
FILTER WATER
DISCHARGE 1.67 m3/kkg
FILTER WASH .313 m3/kkg
ION EXCHANGE 1.25 m3/kkg
CARBON COLUMN .0835 m3/kkg
FLOOR WASH .0209 m3/kkg

FIGURE 11

WATER BALANCE IN A LIQUID SUGAR REFINERY



SURFACE WATER
(10,000) 41.7
Values in M^3/kkg of melt
Parenthetical values in gallons/ ton of melt
EVAPORATOR CONDENSER
(3,300) 13.8
VACUUM PAN CONDENSER
(6,700) 27.9
(10,000) 41.7
SAND FILTER BACKWASH
(90) 0.38
CHAR WASH WATER
(250) 1.04
(350) 1.46
MISCELLANEOUS
(10) 0.04
TRUCK OR CAR WASH AND FLOOR DRAIN (15) 0.06
(60) 0.25
VACUUM PAN WASHOUT
(45) 0.19
BOILER FEED WATER (BLOWDOWN)
(20) 0.08
(20) 0.08
COIL AND HEATER
(7) 0.03
(380) 1.59
MISCELLANEOUS COOLING
(373) 1.56
FRESH WATER
(810) 3.38
TOTAL DISCHARGE
(10,810) 45.1

FIGURE 12

WATER BALANCE FOR A CRYSTALLINE SUGAR REFINERY

Obviously, the factor most affecting total water usage is process variation. As indicated above, crystalline refineries with their requirements for large volumes of barometric condenser cooling water use 60 percent more raw water than liquid refineries. The extremes of this situation may be illustrated by Refinery L-1 which employs no recrystallization in its manufacture of liquid sugar as compared to Refinery C-8 which produces strictly crystalline sugar. The crystalline refinery in this case uses over 600 percent more raw water.

Of all factors affecting water use, one of the most influential is the availability of land for disposal, or conversely, the cost of sewer surcharges. For example, Refineries C-1, C-2, C-4, C-5, C-9, and C-14 discharge process wastes to municipal sewers and average 36.6 cubic meters of water usage per metric ton (8,600 gallons per ton) of melt, while Refinery C-3 which does not discharge to municipal sewers, averages 42.9 cubic meters per metric ton (10,300 gallons per ton)of melt. Refineries L-1 and L-4 employ very similar processes but the former discharges all waste waters to municipal sewers, while the latter uses total impoundage. The difference in water usage is a factor of one to three.

Char Wash

Forty-two percent of all refineries use bone char for decolorization, and these refineries include all of the largest refineries. Tables 6 and 7 give a breakdown of the type of decolorization medium used by each of the 29 refineries currently in operation. The waste water produced by the washing of char is a major waste stream in bone char refineries.

The amount of water used for char washing appears to be more dependent on the opinion of the operator than on any other factor. This is dictated by the fact that in almost all aspects, the use of bone char is more art than science.

The unit flow of char wash water varies from about 0.22 to approximately 0.84 cubic meters per metric ton (53 to 200 gallons per ton) of raw sugar melted. The typical flow would appear to be about 0.6 cubic meters per metric ton (144 gallons per ton).

Other Process Wastes

A non-char refinery, whether crystalline or liquid, uses granular or powdered activated carbon and possibly a combination of carbon and ion-exchange to effect color removal. The major process wastes in a carbon refinery consist of carbon wash water (and in some cases carbon slurry), and possibly ion-exchange regeneration. For liquid refineries, the total process water discharge (total waste water discharge less barometric condenser cooling water) averages approximately 2.5 cubic meters per metric ton (600 gallons per ton) of raw sugar melted.

A major factor considered in the subcategorization of the cane sugar refining segment is the potential difference in process water discharge due to the use of activated carbon versus bone char as the

TABLE 6

DECOLORIZATION MEDIA USED BY EACH CANE SUGAR REFINERY CURRENTLY OPERATING

	Decolorization Media			
Refinery	Bone Char	Activated Carbon	Activated Carbon plus Ion-Exchange	Bone Char, Carbon, and Ion-Exchange
C-1	X			
C-2	X			
C-3	X			
C-4	X			
C-5	X			
C-6	X			
C-7	X			
C-8	X			
C-9	X			
C-10	X			
C-11	X			
C-12	X			
C-13	X			
C-14	X			
L-1			X	
L-2			X	
L-3			X	
L-4			X	
L-5			X	
CL-1				X
CL-2			X	
CF-1		X		
CF-2			X	
CF-3		X		
CF-4		X		
CF-5		X		
CF-6		X		
CF-7		X		
CF-8		X		

TABLE 7

SUMMARY OF TYPES OF DECOLORIZATION MEDIA USED BY CANE SUGAR REFINERS

Refinery Type	Decolorization Media			
	Bone Char	Activated Carbon	Activated Carbon plus Ion-Exchange	Bone Char, Carbon, and Ion-Exchange
Crystalline	14	7	1	0
Liquid	0	0	5	0
Crystalline-Liquid	0	0	1	1
Total	14	7	7	1

decolorization medium in the production of crystalline cane sugar. A substantial difference in discharge flow would mean a substantial cost difference associated with the treatment of this waste water stream. The average process water discharge for all crystalline refineries is 1.86 cubic meters per metric ton (450 gallons per ton) of melt. The average process water discharge for all crystalline refineries utilizing bone char as the decolorization medium is 1.85 cubic meters per metric ton (445 gallons per ton) of melt, while for those using activated carbon is 1.90 cubic meters per metric ton (455 gallons per ton) of melt. This amounts to a difference of 2.6% more process water discharged by crystalline activated carbon refineries. The average process water discharge by those crystalline refineries employing better water conservation techniques is 1.18 cubic meters per metric ton (283 gallons per ton) of melt. The average process water discharge by those crystalline bone char refineries employing better water conservation techniques is 1.17 cubic meters per metric ton (280 gallons per ton) of melt, while for those refineries employing better water conservation techniques and using activated carbon is 1.20 cubic meters per metric ton (288 gallons per ton) of melt. This amounts to a difference of 2.5% more process water discharged by the crystalline activated carbon refineries. (See Tables 8 and 9). It has been determined from this analysis that no significant difference exists in the process water discharge of crystalline bone char versus activated carbon refineries.

Another factor considered was the difference in process water discharge versus size for crystalline cane sugar refineries. As shown in Figure 13, no correlation exists between process water discharge and size of the refinery.

Miscellaneous Water Uses and Waste Streams

Water is used for a number of purposes in a cane sugar refinery in addition to those previously discussed. Fortunately, most of the waste streams produced can be recovered as low purity sweet water. In a well operated refinery essentially all floor drainage is recovered. Condensates produced by the condensation of vapors in all but the last effect of multiple-effect evaporators are used for boiler feed water and other purposes in the refinery.

Sludges, scums, and filter cakes have in some past instances been slurried and discharged to streams. Current practice is to either impound these slurries after desweetening or to handle them dry and provide land disposal.

Minor waste streams may include boiler blowdown, cooling tower blowdown, water treatment sludges, and various wash waters. These are highly variable and minor in individual volume, but may be significant in terms of total pollution load, particularly in a poorly operated refinery.

TABLE 8

PROCESS WATER DISCHARGE FOR CRYSTALLINE CANE SUGAR REFINING (ALL REFINERIES)

Type of Refinery	Number in Study	Average Process Water Discharge (m^3/kkg of melt)	Range (m^3/kkg of melt)
Crystalline (All)	15	1.86	0.6 - 4.0
Bone Char	11	1.85	0.6 - 4.0
Activated Carbon	4	1.90	1.0 - 3.0

$$\text{Difference} = \frac{1.90 - 1.85}{1.90} = 2.6\%$$

TABLE 9

PROCESS WATER DISCHARGE FOR CRYSTALLINE CANE SUGAR REFINING (AVERAGE OF THE BEST)

Type of Refinery	Number in Study	Average Process Water Discharge (m^3/kkg of melt)	Range (m^3/kkg of melt)
Crystalline (Best)	9	1.18	0.6 - 1.4
Bone Char	7	1.17	0.6 - 1.4
Activated Carbon	2	1.20	1.0 - 1.4

$$\text{Difference} = \frac{1.20 - 1.17}{1.20} = 2.5\%$$

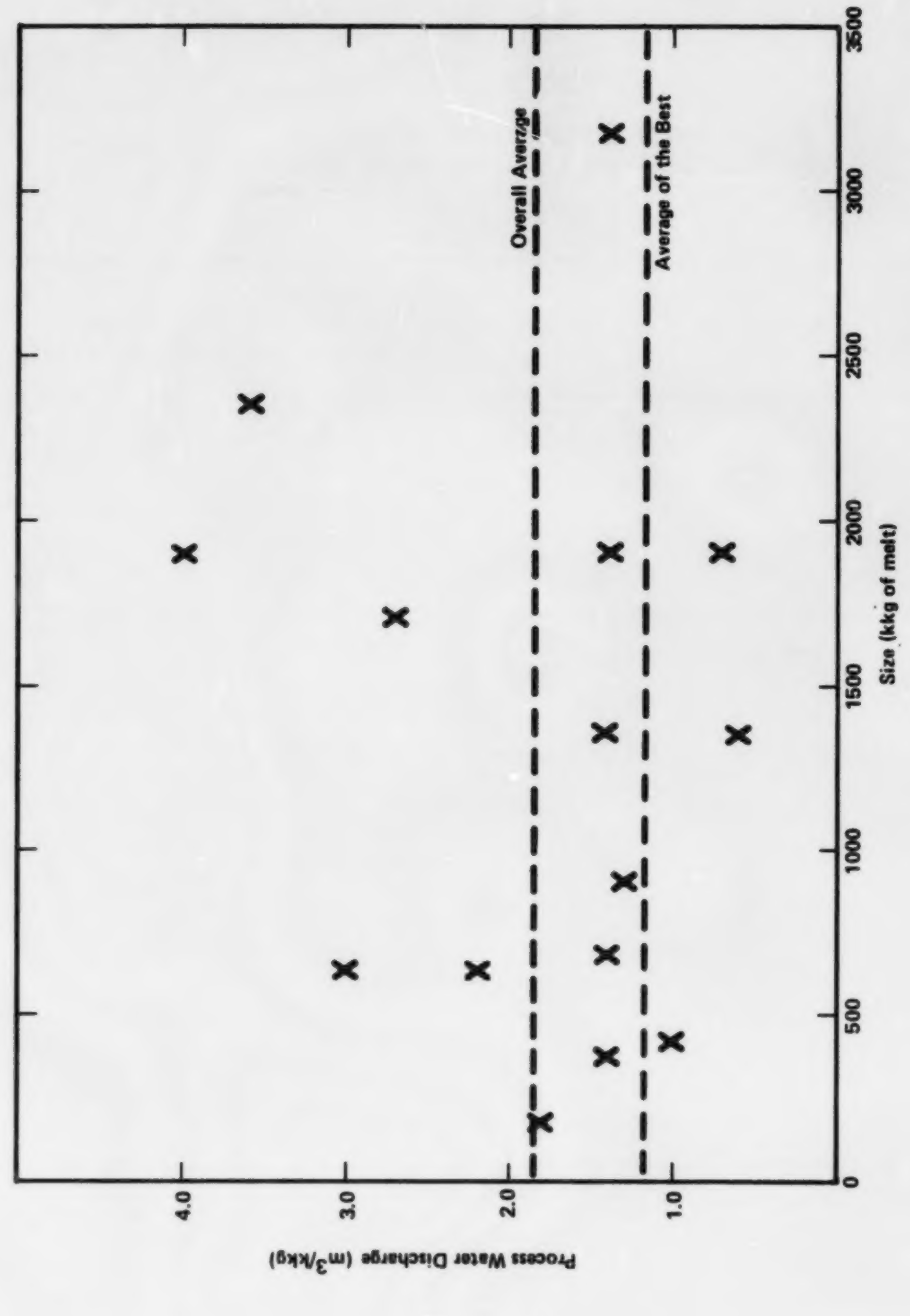


Figure 13
PROCESS WATER DISCHARGE VERSUS SIZE FOR CRYSTALLINE CANE SUGAR REFINING

Barometric Condenser Cooling Water

The major waste water stream in any refinery, in terms of volume, is barometric condenser cooling water produced by contact condensation of vapors from the last effect of multiple-effect evaporators and from vacuum pans. The amount of condenser water used on a unit basis in a refinery varies with the availability of water, the extent of automation in the control of operations, and the thermodynamic relationship between the intake water and the vapors to be condensed; i.e., the higher the temperature of condenser water influent, the larger the volume of cooling water required for vapor condensation.

From the most reliable of data available, the average once-through flow of barometric condenser cooling water for refineries of all categories is nearly 31.5 cubic meters per metric ton (7,550 gallons per ton) of raw sugar melted. For liquid sugar refineries the average is nearer 16.3 cubic meters per metric ton (3,900 gallons per ton) of raw sugar melted, while for crystalline refineries the average is nearly 36.5 cubic meters per metric ton (8,750 gallons per ton) of melt.

Recirculation of barometric condenser cooling water is practiced by several refineries; this technique of reduction of the discharge waste water stream is further discussed in Section VII, Control and Treatment Technology.

WASTE WATER CHARACTERISTICS--CANE SUGAR REFINERIES

The characteristics of the total waste water effluent from a cane sugar refinery vary widely, depending upon the characteristics of the individual waste stream as described below. However, the following major total raw waste streams can be identified:

1. The waste water produced by a crystalline sugar refinery using bone char for decolorization. The majority of waste stream components are char wash water which is a part of the process water stream, and barometric condenser cooling water.

2. The waste water produced by a crystalline sugar refinery using carbon for decolorization. The major waste streams from this type of refinery are barometric condenser cooling water and process water, including ion-exchange regeneration solutions and carbon slurries.

3. The waste water produced by a liquid sugar refinery employing affination and remelt and, therefore, using vacuum pans. The discharge from this refinery is similar to that from the carbon crystalline refinery except that the flow of barometric condenser cooling water is less.

4. The waste waters produced by a liquid refinery which does not use affination, does not remelt, and therefore, does

not use vacuum pans. The discharge from this refinery is similar to the discharge from number three except that the barometric condenser flow is less.

5. The waste waters produced by a refinery which produces both liquid and crystalline sugar by separate processes. The discharge is a combination of numbers two and three.

Barometric Condenser Cooling Water

Theoretically, barometric condenser cooling water should carry net values of only two constituents--sucrose and heat. The sucrose is obtained from entrainment in last-effect evaporators and vacuum pans and heat is a result of heat-exchange between the barometric condenser cooling water and vapors. In terms of waste water characteristics, sucrose appears in barometric condenser cooling water as BOD$_5$, COD, and dissolved solids. In practice, as indicated in Tables 10 and 11, relatively small concentrations of other constituents appear. In some cases these probably appear as a result of analytical error and in other cases because of contamination of the condenser water by unknown waste streams.

The chemical composition of barometric condenser cooling water from a particular refinery is highly variable because of variable operational parameters as well as factors in the design of evaporators and vacuum pans. The characteristics are similar to those from a raw sugar factory and do not significantly vary according to process differences. The BOD$_5$ concentrations vary from 4 mg/l to 39 mg/l and the BOD$_5$ loadings from 0.07 to 1.8 kilograms per metric ton (0.13 to 3.6 pounds per ton) of melt.

Tables 10 and 11 indicate that the volume of barometric condenser cooling water from liquid refineries is less than that from crystalline; however, the BOD$_5$ concentrations are higher. It is estimated that the average crystalline refinery discharges barometric condenser cooling water with a BOD$_5$ concentration of about 12 mg/l and a flow of 36.5 cubic meters per metric ton (8,750 gallons per ton) of melt, while that from a liquid refinery has a BOD$_5$ concentration of approximately 19 mg/l and a flow of 16.3 cubic meters per metric ton (3,900 gallons per ton). The BOD$_5$ loadings for all refineries are generally between 0.15 and 1.0 kilograms per metric ton (0.3 and 2.0 pounds per ton) of melt.

Adsorbents

Commercial adsorbents play an important role in the sugar refining process. While a large portion of the original impurities in the raw sugar is removed during defecation and clarification, there are considerable amounts of colloidal and dissolved impurities that yield only to adsorbent action.

TABLE 10

CONDENSER WATER SUMMARY: LOADINGS*

Refinery	Source	Melt kkg/day	Flow m^3/kkg	BOD5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-1	4	2,350	44.9	0.40	1.1	0.81	44.5	0.02	0.07	0.20	0.13
C-2	3	1,900	16.1	0.07	0.64	0.29			0.0		0.0
C-4	4	1,900	43.2	0.60	1.1	0.43	8.8	0.06	0.29	0.41	0.11
C-5	2	900	42.5	0.21	16.6	0.38					
C-8	2	1,350	62.8	0.94	1.9						
C-9	2	1,900	34.1	0.38	0.75	0.0					
C-11	2	1,350	24.4	0.52	0.83						
L-3	3	775	14.1	0.44	1.4	0.11	0.42	0.0	0.0		0.0
L-4	2	350	26.9	0.16	2.7	0.24					
CL-1	2	1,630	21.4	0.17	0.04	0.02					
CL-2	4	750	47.1	1.8	6.6	1.8					

Data Source: 1) RAPP Data
2) USCSRA Data
3) ESE Data
4) Internal Data

*All values reported in kg/kkg of melt unless otherwise specified

TABLE 11

CONDENSER WATER SUMMARY: CONCENTRATIONS*

Refinery	Source	Melt kkg/day	Flow m^3/day	BOD5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-1	4	2,350	105,600	9	25	18	990	0.4	1.5	4.4	2.9
C-2	3	1,900	30,500	4	40	18			0		0
C-4	4	1,900	82,300	14	25	10	203	1.5	6.8	9.5	2.6
C-5	2	900	38,250	5	391	9					
C-8	2	1,350	84,800	15	30						
C-9	2	1,900	64,700	11	22	0					
C-11	2	1,350	33,000	21	34						
L-3	3	775	10,900	31	99	8	30	0.01	0		0
L-4	4	350	9,400	6	100	9					
CL-1	2	1,630	34,700	8	2	1					
CL-2	4	750	35,300	39	141	38					

Data Source: 1) RAPP Data
2) USCSRA Data
3) ESE Data
4) Internal Data

* All values reported in mg/1 except where otherwise noted

Impurities that are removed by adsorbents may be classified (2) into three types: (1) colloidal material, (2) color-forming compounds, and (3) inorganic constituents.

Although a large number of adsorbents could theoretically be used in sugar refining, only a few are in current use. These include:

1) Bone char
2) Ion-exchange resins, mixed media
3) Ion-exchange resins, specific media
4) Granular activated carbon
5) Powdered activated carbon

Bone char is used in most of the larger sugar refineries in the United States and accounts for approximately 69 percent of all American sugar refining. Bone char is effective in the removal of both inorganic materials (ash) and organic impurities (colorants), and the resulting char wash waters have high concentrations of both ash and colorants. Since the subsequent char kiln does not affect the ash content in the char, and since ash buildup in the char leads to decreased char efficiency, considerable attention is given by refiners to the char washing operation. The basic philosophy is that it is better to use too much water than not enough.

As mentioned in Section III, the first portion of the char wash water is recycled for sucrose recovery. The limiting factors on the amount of char wash recycled are: (1) Sucrose concentrations in the wash water decrease with washing time and eventually reach the point where recovery is impractical; and (2) Ash concentrations in the wash water increase as the sucrose concentrations decrease.

The spent char wash waters have BOD_5 concentrations ranging from 500 to 2,000 mg/l and dissolved solids concentrations ranging from 1,000 to 3,000 mg/l (see Tables 12 and 13). The BOD_5 loading from bone char washing is between 0.15 and 1.7 kilograms per metric ton (0.3 and 3.4 pounds per ton) of raw sugar melted.

Ion-exchange is an effective remover of color as well as ash and is utilized as the decolorization medium in liquid and combination liquid-crystalline refineries. The waste characteristics resulting from the regeneration of an ion-exchange bed are greatly dependent on the particular use of that bed. Ion-exchange is often used in combination with carbon columns, and in these cases the usual practice is to remove organics with the carbon column and then use ion-exchange as a final polishing to remove inorganics. The inorganics of concern include anions as well as cations; for such removal, a "monobed" consisting of both cationic and anionic exchangers is often used. The cation-exchanger can also be used as a polishing step. Most of the organic material found in the sugar liquor is anionic, so that a strongly acidic anion-exchanger (cationic resin) can be used to remove color.

TABLE 12

CHAR WASH WATER SUMMARY: LOADINGS*

Refinery	Source	Melt kkg/day	Flow m^3/kkg	BOD_5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-2	3	1,900	0.66	0.79	1.27	0.03	1.90		0.01		0.0
C-8	4	1,350	0.84	1.65	2.21	0.05					
C-14	3	1,700	0.22	0.17	0.45	0.01	0.37	0.0	0.0		0.0

Data Source:
1) RAPP Data
2) USCSRA Data
3) ESE Data
4) Internal Data

*All values reported in kg/kkg except where otherwise noted

TABLE 13

CHAR WASH WATER SUMMARY: CONCENTRATIONS*

Refinery	Source	Melt kkg/day	Flow m^3/day	BOD_5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-2	3	1,900	1,250	1,200	1,930	46	2,880		9.8		0.15
C-8	4	1,350	1,130	1,960	2,630	57					
C-14	3	1,700	380	750	2,040	59	1,690	2.02	12.2		0.89

Data Source:
1) RAPP Data
2) USCSRA Data
3) ESE Data
4) Internal Data

*All values reported in mg/1 except where otherwise noted

Regeneration of ion-exchange beds usually results in a higher volume of non-recoverable water than those from carbon columns and bone char. If the ion-exchange bed is used primarily as an organic color remover rather than as a final polishing and inorganic remover, the wash waters have higher concentrations of organic carbon and correspondingly higher BOD_5 concentrations. The BOD_5 loading from a liquid refinery using carbon columns for organic color removal as well as for inorganic removal is approximately 2.9 kilograms per metric ton (5.8 pounds per ton) of melt. No analyses from ion-exchange beds used only for inorganic removal have been made, but it appears that the BOD_5 loading is higher than from bone char and granular carbon and considerably lower than from ion-exchange used for organic carbon removal.

Granular carbon is strictly an organic carbon remover and is, therefore, a color remover. The regeneration of granular carbon requires sweetening off with water and heating of the carbon to volatilize organic material, thereby reactivating the surface. Most of the wash water which results from sweetening off a carbon column can be recovered for process because of its sucrose content. A certain amount of water is usually wasted because of low purity. While very little information on the characteristics of this water is available, samples were collected from one liquid sugar refinery. In this refinery a flow of 0.08 cubic meters per metric ton (19.2 gallons per ton) of melt was wasted and the resulting BOD_5 loading was approximately 0.1 kilograms per metric ton (0.2 pounds per ton) of melt.

Miscellaneous Waste Streams

In addition to the waste water resulting from barometric condensers and adsorbent regeneration, there are a number of minor waste streams generated in a cane sugar refinery. These include: floor washings, filter washings, truck and car washings, and boiler blowdown.

The flows associated with these waste streams are highly variable and in some cases can be eliminated by reducing the volume of water used. This results in a waste stream of higher sucrose concentration which can be recycled back into the process. Table 14 indicates characteristics of some of the filter wash waters.

Tables 15 and 16 list waste water characteristics in terms of concentrations and loadings from crystalline, liquid, and combination crystalline-liquid refineries. It is apparent that in terms of unit organic loadings, liquid sugar refineries have higher loadings than do crystalline refineries. This is apparently due to the high organic levels produced in the waste waters resulting from ion-exchange regeneration (all of the liquid sugar installations listed use ion-exchange as an integral part of their process) and to the extent of recrystallization and subsequent remelt practiced by these refineries. An extreme example of this is Refinery L-1, which has the highest waste loading of all refineries listed. It is important to note that this refinery does not remelt sugar (i.e., produces no molasses) and some

TABLE 14

WASTE WATER CHARACTERISTICS OF LIQUID SUGAR REFINERIES

Characteristic	Filter Cake Slurry	Truck & Car Wash	Boiler Blowdown
BOD_5, mg/l	735(3	17,250(1,3	0(1
COD, mg/l	2,120(3	40,300(1,3	0(1
TS, mg/l	3,880(3	6,530(1,3	2,110(1
DS, mg/l	1,430(3	6,480(1,3	2,020(1
TSS, mg/l	2,360(3	50(1,3	90(1
pH	6.3(3	7.2(1,3	5.7(1
NH_3 -N, mg/l	0.32(3	3.04(1,3	0(1
KN, mg/l	12.2 (3	0.49(1,3	0(1
NO_3 -N, mg/l	75.8 (3	1.80(1	0(1
TP, mg/l		0.60(3	2(3
Total Coliform per 100 ml		240(1	0(1
Fecal Coliform per 100 ml		240(1	0(1

(1 RAPP data
(2 USCSRA questionnaire
(3 Internal data

Figures 14 and 15 are illustrations of the estimated flow and loadings for the process water and barometric condenser cooling water, and total discharge streams for the average crystalline and liquid cane sugar refineries, respectively.

TABLE 15

TOTAL WASTE LOADING SUMMARY*

Refinery	Source	Melt kkg/day	Flow m^3/kkg	BOD_5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-1	4	2,350	48.5	0.63	1.9	0.92	46.9	0.02	0.08	0.21	0.14
C-2	3	1,900	16.7	1.0	1.9	0.34			0.01		0.00
C-3	2	2,800	42.9	1.8	5.0	3.6					
C-4	2	1,900	44.6	1.7	3.1	1.4					
C-5	2	900	43.8	1.1	17.1	12.5					
C-6	2	170	42.4	1.9	1.5	0.08					
C-7	2	3,175	25.8	2.4	6.6						
C-8	2	1,350	64.2	1.7	3.4	0.06					
C-9	2	1,900	38.1	1.7	3.5	0.34					
C-11	2	1,350	25.0	2.1	3.4	1.2					
C-14	2	1,700	3.32	0.87	1.5	1.3					
L-1	2	275	10.5	5.1	6.1	8.4					
L-3	3	775	16.0	3.7	6.6	0.94	16.2	0.00	0.01		0.03
L-4	2	350	30.0	2.2	5.7	7.4					
CL-1	2	1,650	22.5	2.3	5.6	1.1					
CL-2	1	750	47.9	1.1				0.00	0.00	0.00	0.00

Data Source: 1) RAPP Data 3) ESE Data
2) USCSRA Data 4) Internal Data

*All value reported in kg/kkg of melt unless otherwise specified.

TABLE 16

TOTAL FLOW SUMMARY*

Refinery	Source	Melt kkg/day	Flow m^3/day	BOD5	COD	TSS	DS	NH_3-N	Kjel-N	NO_3-N	TP
C-1	4	2,350	114,000	13	39	19	966	0.46	1.66	4.33	2.80
C-2	3	1,900	31,900	60	115	20			0.60		0.00
C-3	2	2,800	120,000	43	116	85					
C-4	2	1,900	84,800	39	70	30					
C-5	2	900	39,400	24	391	286					
C-6	2	170	7,200	46	36	2					
C-7	2	3,175	82,000	92	255						
C-8	2	1,350	86,700	26	53	1					
C-9	2	1,900	72,300	45	91	9					
C-11	2	1,350	33,800	85	136	46					
C-14	3	1,700	5,650	263	460	397					
L-1	2	275	2,900	487	579	796					
L-3	3	775	12,400	230	415	59	1,014	0.03	0.51		1.61
L-4	2	350	10,500	72	190	247					
CL-1	2	1,650	37,200	104	247	51					
CL-2	1	750	35,900	22				0.0	0.02	0.0	0.0

Data Source:
1) RAPP Data
2) USCSRA Data
3) ESE Data
4) Internal Data

*All values reported in mg/l except where otherwise noted impurities that would otherwise be contained in molasses must leave the refinery in its waste water. This principle is true to a lesser extent for other liquid and liquid-crystalline refineries that remelt to varying degrees. Refinery L-3, for example, does not remelt sugar in its primary product line but must recrystallize in a side product line (refer to Figure 9) to effect recovery of additional sugar and molasses by-product. This refinery still produces a BOD_5 loading of 3.70 kilograms per metric ton (7.40 pounds per ton) of raw sugar melted. The impact of ion-exchange on the BOD_5 loading from a refinery is illustrated by the fact that 77 percent of the total BOD_5 loading at the latter refinery is due to ion-exchange regeneration waste water.

Figures 14 and 15 are illustrations of the estimated flow and loadings for the process water and barometric condenser cooling water, and total discharge streams for the average crystalline and liquid cane sugar refineries, respectively.

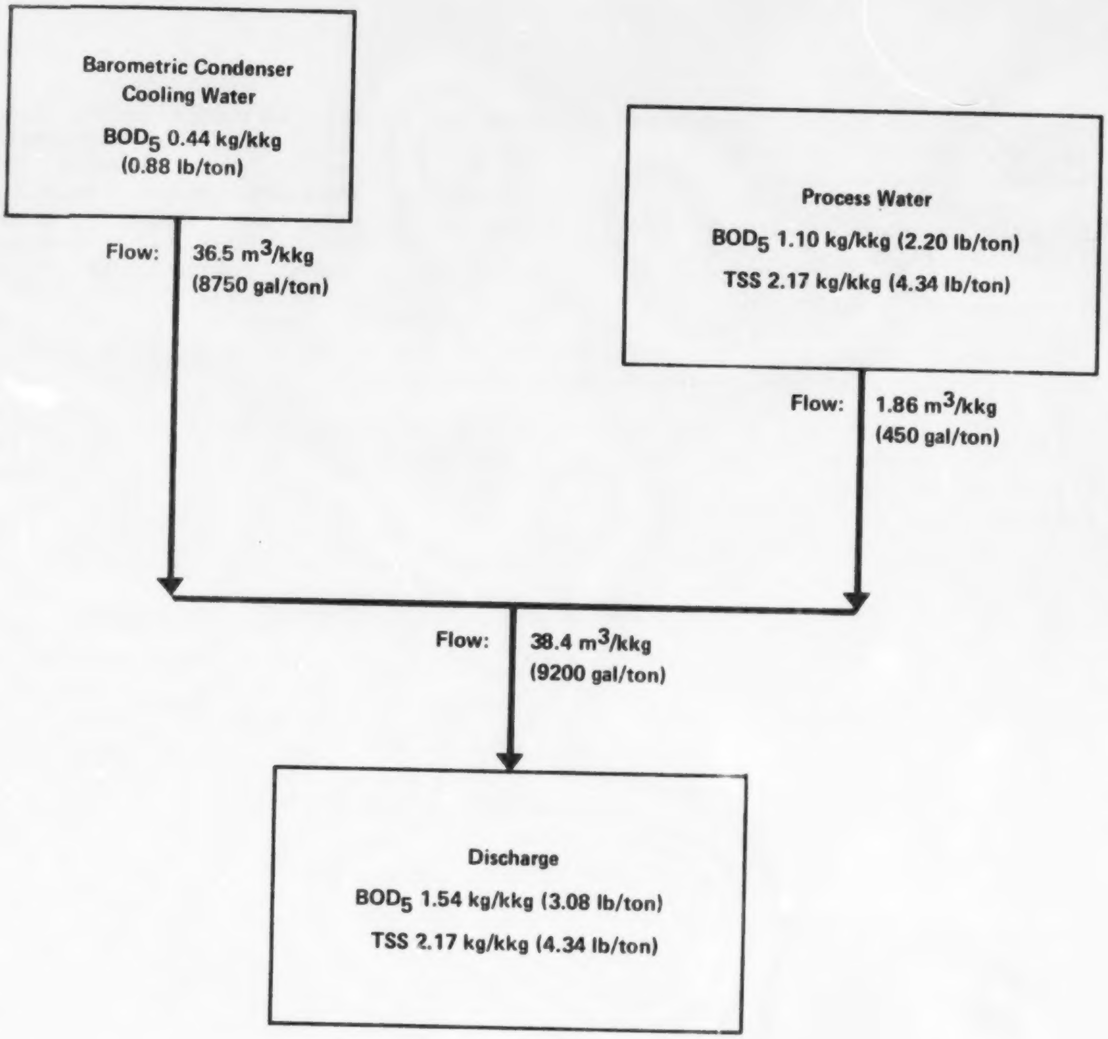

Barometric Condenser Cooling Water
BOD5 0.44 kg/kkg (0.88 lb/ton)
Flow: 36.5 m3/kkg (8750 gal/ton)
Process Water
BOD5 1.10 kg/kkg (2.20 lb/ton)
TSS 2.17 kg/kkg (4.34 lb/ton)
Flow: 1.86 m3/kkg (450 gal/ton)
Flow: 38.4 m3/kkg (9200 gal/ton)
Discharge
BOD5 1.54 kg/kkg (3.08 lb/ton)
TSS 2.17 kg/kkg (4.34 lb/ton)

Figure 14
RAW WASTE LOADINGS AND WATER USAGE FOR THE AVERAGE CRYSTALLINE CANE SUGAR REFINERY

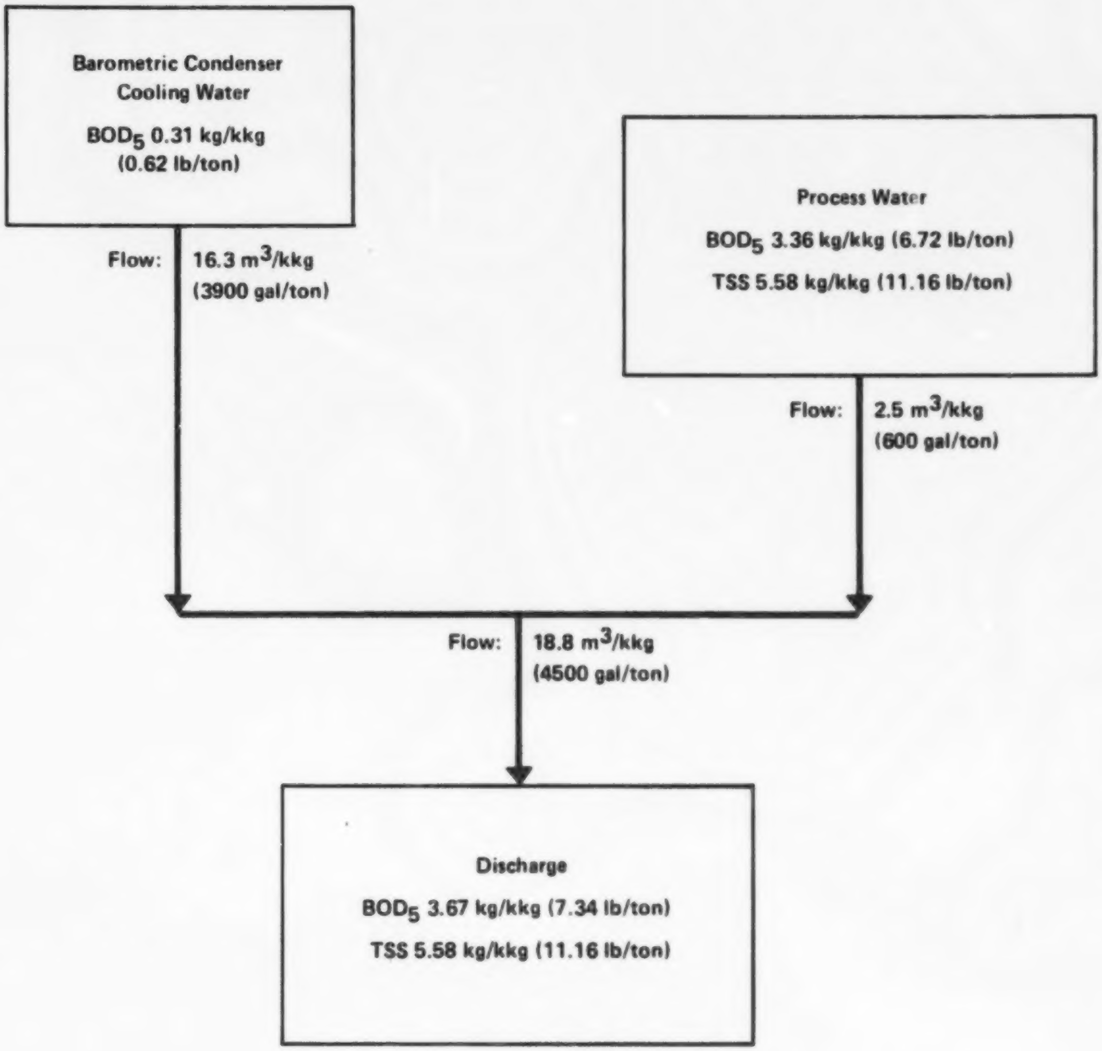

Barometric Condenser Cooling Water
BOD5 0.31 kg/kkg (0.62 lb/ton)
Flow: 16.3 m3/kkg (3900 gal/ton)
Process Water
BOD5 3.36 kg/kkg (6.72 lb/ton)
TSS 5.58 kg/kkg (11.16 lb/ton)
Flow: 2.5 m3/kkg (600 gal/ton)
Flow: 18.8 m3/kkg (4500 gal/ton)
Discharge
BOD5 3.67 kg/kkg (7.34 lb/ton)
TSS 5.58 kg/kkg (11.16 lb/ton)

Figure 15
RAW WASTE LOADINGS AND WATER USAGE FOR THE AVERAGE LIQUID CANE SUGAR REFINERY

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

Major waste water parameters of pollutional significance for the cane sugar refining segment include BOD (5-day, 20° Centigrade), suspended solids, and pH. Additional parameters of significance include COD, temperature, sucrose, alkalinity, total coliforms, fecal coliforms, total dissolved solids, and nutrients (forms of nitrogen and phosphorus). On the basis of all evidence reviewed, there do not exist any purely hazardous or toxic pollutants (e.g., heavy metals, pesticides) in wastes discharged from cane sugar refineries.

When land disposal of waste water is practiced, contribution to ground water pollution must be prevented. If deep-well injection is used, all practices must be in accordance with the Environmental Protection Agency's "Policy on Subsurface Emplacement of Fluids by Well Injection" with accompanying "Recommended Data Requirements for Environmental Evaluation of Subsurface Emplacement of Fluids by Well Injection"(5).

MAJOR WASTE WATER CONTROL PARAMETERS

The following selected parameters are determined to be the most important characteristics of cane sugar refining wastes. Data collected during the preparation of this document was limited in most cases to these parameters. Nevertheless, the use of these parameters adequately describes the waste water characteristics of the refining industry. BOD (5-day), suspended solids, and pH are the parameters selected for effluent limitations guidelines and standards of performance for new sources.

Biochemical Oxygen Demand (5-day BOD)

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. For this reason, in waste water treatment, it is commonly used as a measure of treatment efficiency. The BOD does not in itself cause direct harm to a water system, but the matter which it measures may exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the

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development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely by conditions of suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

BOD is a particularly applicable parameter for the sugar industry since sucrose is highly biodegradable. It is significant also to ground water pollution control in that it is possible for biodegradable organics to seep into ground water from earthen settling or impoundage basins. The primary disadvantage of the BOD test is the time period required for analysis (five days is normal) and the considerable amount of care which must be taken in order to obtain valid results.

Typical BOD_5 levels in both crystalline and liquid cane sugar refining are quite high, ranging from several hundred to several thousand mg/l for certain waste streams. Discharge of such wastes to surface waters can result in oxygen depletion and damage to aquatic life.

Total Suspended Solids

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers.

These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, State and Regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water used by the textile, pulp and paper, beverage, dairy products, laundry, dyeing, and photography industries, and used in cooling systems and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area.

Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low.

Total suspended solids serve as a parameter for measuring the efficiency of waste water treatment facilities and for the design of such facilities. In sugar refining waste waters, most suspended solids are inorganic in nature, originating from process flows such as char wash and carbon slurries. Barometric condenser cooling water is essentially free of net suspended solids.

pH, Acidity, Alkalinity

Acidity and Alkalinity. Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Aklalinity is caused by strong bases and the salts of strong alkalies and weak acids.

pH. The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. pH values lower than 7 indicate acidity while values higher than 7 indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bacterial effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

ADDITIONAL PARAMETERS

Chemical Oxygen Demand

Under the proper conditions, the chemical oxygen demand (COD) test can be used as an alternative to the BOD test. The COD test is widely used as a means of measuring the total amount of oxygen required for oxidation of organics to carbon dioxide and water by the action of a strong oxidizing agent under acidic conditions. It differs from the BOD test in that it is independent of biological assimilability. The major disadvantage of the COD test is that it does not distinguish between biologically active and inert organics. The major advantage is that it can be conducted in a short period of time, or continuously in automatic analyzers. In many instances, COD data can be correlated to BOD data and the COD test can then be used as a substitute for the BOD test.

Considerable difficulties occur with the COD test in the presence of chlorides, and it must be noted that barometric condenser cooling water in a number of refineries consists of brackish water.

No definitive relationship between BOD (5-day) and COD can be established at the present time. Therefore, it is concluded that effluent limitations guidelines and standards of performance cannot be established for COD at present.

Bacteriological Characteristics

No bacteriological problems exist in the production of refined cane sugar due to the fact that any bacteria present in the product prior to evaporation are destroyed in the evaporation process. There is no introduction of microorganisms in the refining process.

Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present, activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development; warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F.

Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic plant nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperature increases, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 99°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The effect of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, the formation of sludge gas, the multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the aesthetic value of a water source.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

The temperatures of waste waters discharged from cane sugar refineries can present a problem in the case of barometric condenser cooling water and other miscellaneous cooling waters. These streams are normally discharged at temperatures in the range of 16° to 43°C (60° to 110°F), but may in some instances be as high as 63°C (145°F). The discharge of these heated waters, with inadequate dilution, may result in serious consequences to aquatic environments.

Nutrients

Forms of nitrogen and phosphorus act as nutrients for the growth of aquatic organisms and can lead to advanced eutrophication in surface water bodies.

Nitrogen. Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria. Nitrite (NO_2), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions exist. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

In most natural water the pH range is such that ammonium ions (NH_4^+) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one-half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l of un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and the dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

From the limited amount of data available, with regard to this parameter, ammonia (NH_3-N) concentrations of 0.01 to 1.5 mg/l occur in barometric condenser cooling water and of 0 to 0.46 mg/l occur in the total raw effluent from cane sugar refineries.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptons are diarrhea and diuresis. Drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants.

Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer.

From the limited data available with regard to this parameter, nitrate (NO_3-N) concentrations of 4.4 to 9.5 mg/l occur in barometric condenser cooling water and of 0 to 4.33 mg/l occur in the total raw effluent from cane sugar refineries.

Phosphorus. During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element of all of the elements required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growth.

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating, water skiing, and sometimes fishing may be impossible because of the mass of vegetation that serves as a physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact and serve as a desired substrate and breeding ground for flies.

Phoshphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues.

Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

From the limited amount of data available with regard to this parameter, total phosphorus concentrations of 0-2.9 mg/l occur in barometric condenser cooling water and of 0-2.8 mg/l occur in the total raw effluent from cane sugar refineries.

Total Dissolved Solids

In natural waters the dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances. In cane sugar refinery effluents, dissolved solids are more often organic in nature, originating from sucrose.

Many communities in the United States and in other countries use water supplies containing 2000 to 4000 mg/l of dissolved salts, when no better water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4000 mg/l of total salts are generally considered unfit for human use in temperate climates, although in hot climates such higher salt concentrations can be tolerated. Waters containing 5000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh-water fish may range from 5,000 to 10,000 mg/l, according to species and prior acclimation. Some fish are adapted to living in more saline waters, and a few species of fresh-water forms have been found in natural waters with salt concentrations ranging from 15,000 to 20,000 mg/l. Fish can slowly become acclimated to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. At 5,000 mg/l water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and cause interference with cleanliness, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion.

Specific conductance is a measure of the capacity of the ions present in solution to convey an electric current. This property is related to the total concentration of ionized substances in water and to water temperature. This property is frequently used as a substitute method of quickly estimating the dissolved solids concentration.

Total dissolved solids may reach levels of 1,000 milligrams per liter in certain refinery waste water streams. In once-through barometric condenser cooling water, where entrained sucrose contributes dissolved solids, the concentration is typically 20 milligrams per liter. Where land impoundage of waste waters is employed, the dissolved solids concentration in seepage may considerably exceed raw waste water values.

Sugar Analysis

Analysis for sucrose content is important in process control as an indicator of sugar loss. The two common tests used are the alphanapthol and resorcinol methods. Neither of these methods provides high accuracy at low sucrose concentrations, but each may serve a useful purpose by indicating slug loads of sugar and thus provide a danger signal for improper operation of evaporators or vacuum pans, or for spills of sugar or molasses. Due to the inaccuracy of the test at low levels and to the fact that sugar content is also measured by BOD, the sugar analysis is not an adequate parameter for guidelines establishment.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

Current technology for the control and treatment of cane sugar refinery waste waters consists primarily of process control (recycling and reuse of water, prevention of sucrose entrainment in barometric condenser cooling water, recovery of sweet waters), impoundage (land retention), and disposal of process water to municipal sewer systems.

The general scope of current technology is that the volume of process water is sufficiently low that it can be handled by end-of-line treatment and disposal systems, whereas the much higher volume of barometric condenser cooling water makes it impractical to treat. This position is illustrated by the fact that few refineries release substantial amounts of untreated process waters to receiving streams while all but five refineries discharge barometric condenser cooling water to surface water bodies.

IN-PLANT TECHNOLOGY

IN-PLANT CONTROL MEASURES AND TECHNIQUES IN THE CANE SUGAR REFINING INDUSTRY

In-plant control measures are essential in the total effort for pollution control in cane sugar refineries. In-plant control refers to the operational and design characteristics of the refinery and their impact on total waste management. Specific elements are water utilization and conservation, housekeeping techniques, and any operational or design factors that affect waste water quantity and/or quality. A primary portion of in-plant control is for the prevention of sugar loss and thus is an extension of historical efforts. To the refiner the loss of sugar in waste water represents lost money; to the environmentalist it is an organic pollutant. Other measures of in-plant control include the facilitation of dry-handling techniques for sludges and filter cakes, maximum recovery and reuse of various process streams, and improved housekeeping practices.

Raw Sugar Handling. Raw sugar is normally delivered to refineries by truck, rail car, barge, or ship. The unloading of the raw sugar at the receiving area offers an opportunity for sugar spillage, and the periodic washdown of the receiving area produces a variable waste stream with a high sugar content. In one refinery visited, raw sugar conveyor belts were routinely washed down and the resulting sugar solutions were allowed to flow into a surface water body, carrying with them an indeterminable amount of BOD_5.

Most refineries recover floor washings in the receiving area to some extent--some refineries almost in total. The practice in some refineries is to recover as much spilled sugar as possible by sweeping, then discharge subsequent rinse water to waste. A minimal effort at sugar loss prevention through equipment modification and improved housekeeping can essentially prevent the loss of sugar and its resulting pollutant load from the raw sugar receiving area.

Truck and Car Wash. The tank trucks and rail tank cars that transport liquid sugar and edible syrups must be maintained under sanitary conditions. This normally involves cleaning of the tanks with steam and water after each use. The first few minutes of washing produces a sweet water that is of sufficient sucrose concentration to allow economical recovery for processing. The sucrose concentration in the wash water effluent after the first few minutes is considered by most refiners to be too low for recovery and is wasted. This stream can be minimized by maximizing recovery, but in any event the stream is small in volume and a minor contribution to total process waste water flow.

Floor Wash. Since any bacteriological contamination to the raw sugar syrup prior to evaporation is eliminated by evaporation, the recovery of essentially all floor wash drains as sweet water is possible and is practiced in some refineries.

Barometric Condenser Cooling Water. The development of calandria-type vacuum pans and evaporators in the sugar industry has afforded increased boiling rates, but at the same time the possibility of sucrose entrainment in the barometric condenser cooling water has increased. Sucrose entrainment represents an economic loss to the refiners as well as an organic pollutant load to the environment in the condenser water effluent. All sugar refineries employ some means to reduce entrainment, with the motive in the past being primarily an economic one.

Entrainment is a result of liquid droplets being carried out with water vapors in evaporators and vacuum pans. There are three important factors which affect the efficiency of entrainment control:

(1) Height of the vapor belt (vapor height)
(2) Operation and maintenance
(3) Liquid-vapor separation devices

One of the most important factors in determining liquid carryover is the height the liquid bubbles must rise before entering the relatively high velocity area of the discharge tube. If the height of the vapor belt is of sufficient magnitude, most liquid droplets will fall back into the boiling liquor due to gravity and be removed from the vapor before exiting the evaporator or vacuum pan. It has been found from experience that the vapor height should be at least 250 percent of the height of the calandria tubes to minimize entrainment. Vapor heights in the cane sugar refining industry have been generally found to be more adequate than those in raw sugar factories. However, when existing vapor heights are insufficient, they can be increased by installing a spacer in existing equipment. This has been done in several cases for the purpose of increasing evaporation capacity, but entrainment reduction has been a secondary result.

In addition to proper design, proper operation of the evaporators and vacuum pans is essential in minimizing sucrose entrainment. It is important to maintain the liquid level in evaporators and vacuum pans near the design level; in essence, if the liquid level is increased, the vapor height is decreased. An important variable which must be carefully controlled is the pressure inside the vessel. If the pressure is suddenly decreased, flash evaporation is likely to occur resulting in an increase in boiling rate and subsequent liquid carryover. Automatic controls are available for the operation of evaporators and pans and these have been installed in a number of refineries. The typical refinery has liquid level controllers on all evaporator bodies and absolute pressure control on last bodies of multiple effects and on vacuum pans.

In addition to proper design and operation, a number of devices can be installed to separate liquid droplets from the vapors. Baffle arrangements which operate on either centrifugal or impingement principles are commonly used. The Serner separator (7), a type of baffle arrangement, is used in several refineries. Figure 16 shows the effectiveness of entrainment prevention devices, including Serner separators, used in conjunction with other baffles and direction reversals, based on experience in a particular installation. The total BOD_5 reduction in this case is 84 percent. Higher reductions are considered possible with careful design coupled with proper operation.

Demisters have been found to be applicable to entrainment reduction in certain cases. These devices, which consist basically of a wire mesh screen serving the dual purpose of impingement and direction change, were used to a large extent in the Cuban sugar industry before 1960 and have been used to a limited extent in the United States. One refinery, upon the installation of demisters in most of its evaporators and vacuum pans experienced a 50 percent reduction in barometric condenser cooling water COD. However, during the same maintenance program, changes were made in the baffles and other control equipment, and the amount of reduction due solely to the demisters remained unclear.

At least two major refineries use partial surface condensers as heat exchangers in the exhaust ducts prior to barometric condensation. These units not only affect liquid-vapor separation but also capture heat from the vapors, and have been installed for the latter purpose.

Total surface condensers have also been considered but in general they have been rejected, primarily due to the costs associated with installation, but also for a number of other reasons including operational problems and the questionable benefits associated with their use. A total surface condenser condenses vapors by indirect (non-contact) cooling resulting in no sucrose loss in condenser water and a stream of hot condensate that must be discharged because of its low sucrose content.

One potential problem with surface condensers is fouling. Most refineries use low quality surface (river or estuarine) water for conden-

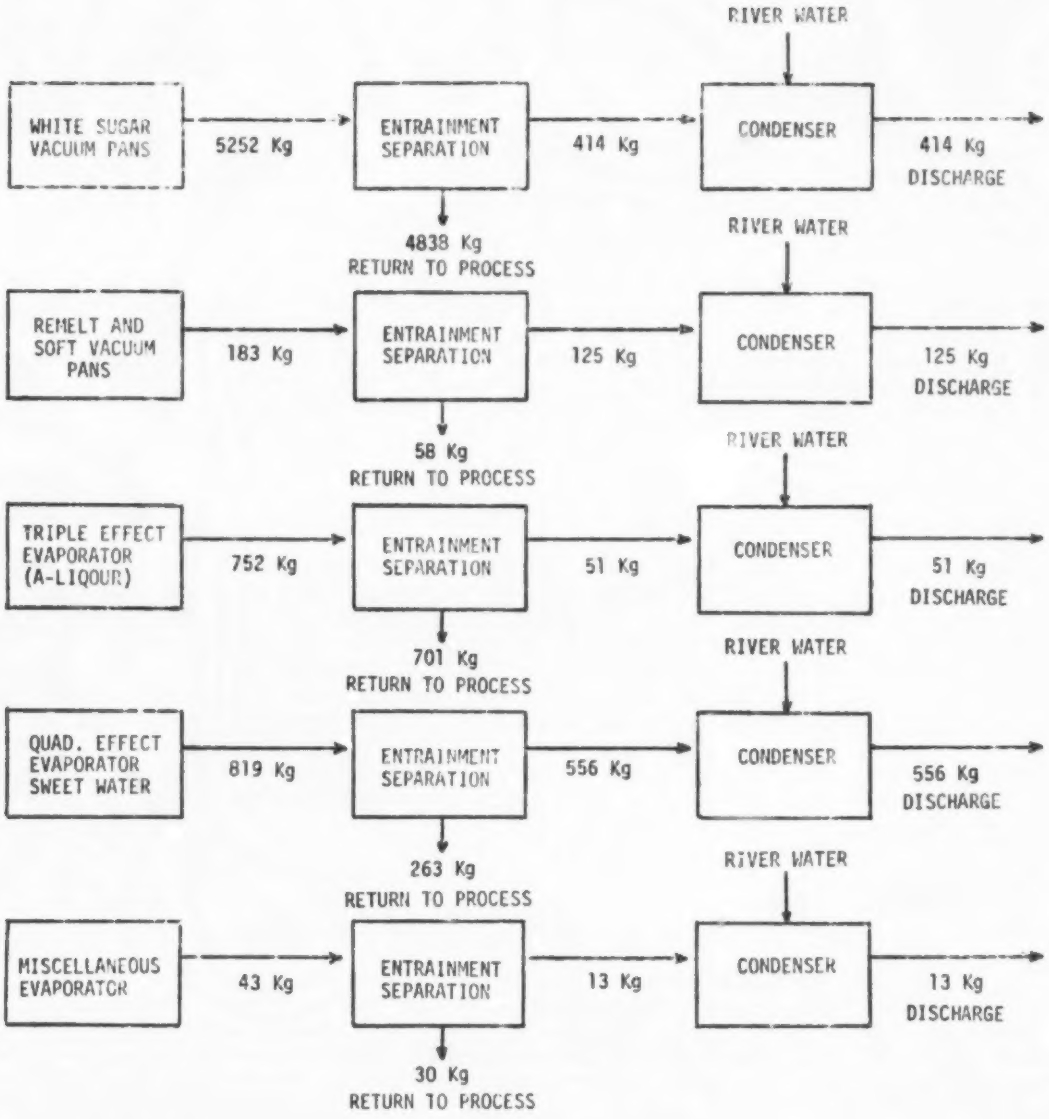
RIVER WATER
WHITE SUGAR VACUUM PANS
5252 Kg
ENTRAINMENT SEPARATION
414 Kg
CONDENSER
414 Kg DISCHARGE
4838 Kg RETURN TO PROCESS
RIVER WATER
REMELT AND SOFT VACUUM PANS
183 Kg
ENTRAINMENT SEPARATION
125 Kg
CONDENSER
125 Kg DISCHARGE
58 Kg RETURN TO PROCESS
RIVER WATER
TRIPLE EFFECT EVAPORATOR (A-LIQOUR)
752 Kg
ENTRAINMENT SEPARATION
51 Kg
CONDENSER
51 Kg DISCHARGE
701 Kg RETURN TO PROCESS
RIVER WATER
QUAD. EFFECT EVAPORATOR SWEET WATER
819 Kg
ENTRAINMENT SEPARATION
556 Kg
CONDENSER
556 Kg DISCHARGE
263 Kg RETURN TO PROCESS
RIVER WATER
MISCELLANEOUS EVAPORATOR
43 Kg
ENTRAINMENT SEPARATION
13 Kg
CONDENSER
13 Kg DISCHARGE
30 Kg RETURN TO PROCESS

FIGURE 16

ENTRAINMENT REDUCTION

ser cooling. While total surface condensers have not been used in refineries, a comparison can be made with surface heat exchangers used for air and oil coolers of turbine generators. The general experience of the sugar industry has been that raw river water is unacceptable for such applications because of fouling (13).

A second problem area in the use of surface condensers is vacuum control on the vacuum pans. For proper operation of a vacuum pan, an absolute pressure with a tolerance of plus or minus 0.003 atmospheres (0.1 inch mercury) must be maintained. Adjustments to the absolute pressure, made necessarily by variations in calandria steam pressure, feed density, and non-condensible leakage, can be made with a barometric condenser by changing the flow in the condenser; however, the lag time associated with a surface condenser makes absolute pressure control considerably more difficult and could actually increase sugar entrainment.

The physical installation of surface condensers would be a problem in many refineries, and in some cases an almost insurmountable one. Vertical height when unavailable can often be obtained by raising the roof of a refinery, but horizontal space may be achieved only with considerable difficulty. The weight of surface condensers could possibly cause structural problems in older refineries. The units would have to be installed on the fourth or fifth floor of a building that might be a century old. The structural analysis required to ensure the feasibility of doing so could be extremely difficult.

USCSRA has estimated (13) that in a typical 1900 metric ton (2100 ton) refinery, surface condensers would approximately double required pumping energy, increase electrical requirements by about 1000 kilowatts, and require 11,350 to 13,620 kilograms per hour (25,000 to 30,000 pounds per hour) additional steam capacity.

Recirculation of barometric condenser cooling water through a cooling tower is feasible and is practiced at three refineries. Spray ponds have proved to be feasible for the cooling and recirculation of barometric condenser cooling water for two small rural refineries, for several cane sugar factories, and for a number of beet sugar plants. However, the land required for these facilities generally prohibits their use for urban refineries.

One large urban refinery recycles barometric condenser cooling water through a cooling tower and discharges on the average about two to three percent of the flow as blowdown. Cooling towers, while expensive, might be applicable to other refineries and offer a means of reducing waste water volume; however, in northern climates winter temperatures would interfere with operation, and in dense urban areas wind blown sprays and odors can present problems. These problems can be reduced by proper design and operation, and probably eliminated for most wind conditions.

Filter Cake. Most refineries use pressure filters such as the Valley or Industrial type for removing impurities from sugar liquors. Filter aid, usually diatomaceous earth, is used with the filters. When the pressure drop across the filter increases to an unacceptable value or when the filter efficiency drops, the filter cake is removed. The desweetened cake is semi-dry (about 50 percent moisture) and may be handled in that form or it may be slurried for pumping. In the dry form it is normally conveyed to trucks which in turn transport the material to landfill or other land disposal. In the slurried form it may be pumped to impoundage or to a municipal treatment system. A major portion of the cake can be recovered in a kiln by revivification of the filter aid. An existing system for filter cake recycle and land disposal is illustrated in Figure 17. In this system approximately 80 percent of the cake is conveyed to a multiple hearth kiln where the cake is heated to about 816°C (1,500°F). Revivified filter aid is discharged from the kiln, pulverized, and returned to the filtration step of the refining process. Makeup filter aid is added to the system as required. The installation of a continuous carbonation process for lime mud slurry, to make it suitable for vacuum filtration and removal of sugar by washing, is reported by one refinery to have reduced total settleable solids by 96 percent and BOD_5 by 20 percent.

Adsorbent Regeneration. In-plant modifications for the reduction of waste waters resulting from the regeneration of bone char, carbon columns, and ion-exchange resins are practically non-existent, although there are some minor, mainly operational, modifications to reduce waste water loads which include:

(1) Recovery of waste waters with lower sucrose concentrations, i.e., recovery of a greater portion of spent char wash water,

(2) Reduction in the volume of wash water used to sweeten off bone char and carbon columns, and greater dependence on volatilization of organics,

(3) Elimination or reduction in the use of ion-exchange as an organic color remover.

These modifications are merely proposals and the implications of their adaptation are not fully known; research on this subject is needed. At present, control and treatment of these wastes is restricted to end-of-line treatment.

WASTE TREATMENT TECHNOLOGY

TREATMENT AND DISPOSAL TECHNOLOGY CURRENTLY AVAILABLE TO THE CANE SUGAR REFINING INDUSTRY

The following is a discussion of various end-of-pipe treatment technologies available to the cane sugar refining segment of the cane sugar processing industry. These technologies range from preliminary

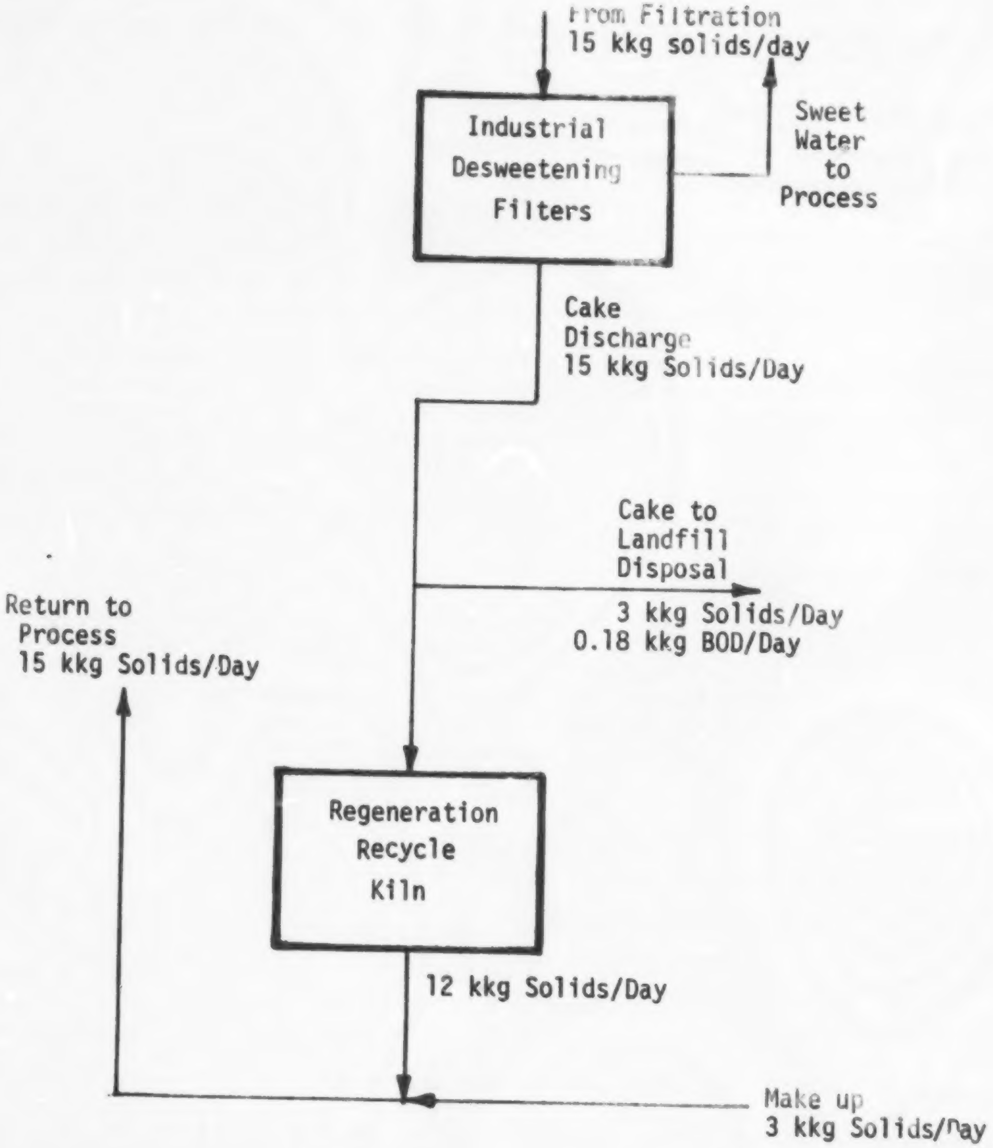
From Filtration
15 kkg solids/day
Industrial
Desweetening
Filters
Sweet
Water
to
Process
Cake
Discharge
15 kkg Solids/Day
Cake to
Landfill
Disposal
3 kkg Solids/Day
0.18 kkg BOD/Day
Return to
Process
15 kkg Solids/Day
Regeneration
Recycle
Kiln
12 kkg Solids/Day
Make up
3 kkg Solids/Day

FIGURE 17

FILTER CAKE RECYCLE SYSTEM

treatment systems to advanced waste treatment systems and systems of ultimate disposal.

Preliminary Treatment Systems

Flow Equalization Tanks. Flow equalization facilities consist of a holding tank and pumping equipment designed to reduce the fluctuations in flow of waste effluent streams. They can be economically advantageous whether a processing plant is treating wastes or discharging into a city sewer after some pretreatment. The equalizing tank stores waste water either for recycle or to feed the flow uniformly to treatment facilities throughout a 24-hour period.

Sedimentation. Sedimentation without prior chemical addition may prove to be an effective means of solids removal. This can serve the purpose of reducing the solids loading on another part of the treatment system. If settling tanks rather than lagoons are used, the settled solids must be collected and withdrawn from the bottom of the tank. Solids may be continuously collected and withdrawn by the utilization of mechanical scrapers which move slowly along the bottom of the settling tank.

Chemical Treatment

pH Adjustment. Acids and caustics are used to remove scale deposits from evaporators and vacuum pans. Lime or phosphoric acid may be added to aid in the clarification of screened melt liquor. Biological systems function at their optimum when the pH is neutral (7.0), but will operate effectively within the pH range of 6.0 - 9.0. When necessary, the pH may be adjusted, with the proper addition of acid or base, to within these limits; this assures the proper environment for the active biota.

Chlorination. Chlorination is used for odor control and also in municipal water treatment as a disinfectant. Chlorine is available in granular, powdered, or liquid form. Adding chlorination to a treatment process presents the need to construct chlorine handling facilities consisting of storage, phase conversion, mixing, and effluent detention facilities. Since chlorine is a hazardous substance, special safety precautions in storage and handling are required. Dose rates for chlorine for domestic sewage are usually in the range of 3 to 15 parts per million with detention times of up to one hour in duration. Dosage should be high enough to provide a chlorine residual in the effluent to assure protection against pathogenic bacteria.

Chlorination is used to inhibit algae growth. This is of special importance for correcting one type of bulking sludge problem in some activated sludge plants.

Chlorination may also be used for disinfection and to oxidize residual organic material. It is practiced on treated waste waters to a limited degree. This practice can be expected to become common in order to permit the recycle of highly purified waters.

Chlorine also provides a residual protection against bacteria that other disinfectants such as ozone or bromine do not provide.

Nutrient Addition. Cane sugar refinery waste waters are deficient in both nitrogen and phosphorus with regard to the ratio of these elements to organic matter which is required for optimum biological treatment. This situation may be corrected with nutrient addition (ammonia and phosphoric acid, for example) prior to biological treatment. The nutrients should be added after primary settling to avoid their loss in the solids removed by the settling device.

Primary Treatment Systems

Settling, Sedimentation, and Clarification. A substantial portion of suspended solids may be separated by settling, sedimentation, or clarification. Settling involves the provision of a sufficiently large tank or pond in order that the velocity of the waste water streams be reduced. The forces resulting from density differences between the suspended solids and the waste water come into affect and the solids settle out.

Clarifiers operate on the same principle, with the addition of mild mechanical agitation to assist in the settling process and in the removal of suspended solids. Clarifiers are also used as a part of the activated sludge process, serving as an initial step preceding biological treatment and to separate sludge for return to the aeration step or to anaerobic digestion.

Settling ponds or clarifiers are also used as a final step in biological systems for the removal of biological solids prior to the discharge of treated waste waters.

Settled solids from the bottom of the clarification unit in the form of a sludge may be pumped to a rotary vacuum filter, where the slurry is concentrated by removal of water which is returned to the clarifier. The outside surface of the filter cylinder is covered with a filter medium (screen or cloth). The lower portion of the filter is suspended in the liquid slurry. As the drum rotates, the vacuum which is maintained within the cylinder forces liquid into the cylinder while leaving a solids layer on the outside of the filter medium. As the drum rotates, a scraper mechanism removes solids from the surface of the filter medium. This method of solids thickening has been widely used in both industrial and municipal waste water treatment.

Biological Treatment Systems

The treatment of waste effluents by biological methods is an attractive alternative when a high portion of the biodegradable material is in soluble form, as is the case in the cane sugar refining segment of the sugar processing category.

Many types of microorganisms remove organic materials from waste waters. Those most commonly used in treatment systems are heterotrophs, which utilize organic carbon as an energy source and for growth. Some are aerobic and require molecular oxygen for converting wastes to carbon dioxide and water. Others are anaerobic and grow in the absence of molecular oxygen. Anaerobic microorganisms grow more slowly than do aerobes and produce less sludge per unit of waste treated than do aerobic microorganisms. Anaerobes also release acids and methane, and their actions on sulfur-containing waste waters may create odor problems. Some microorganisms are facultative or grow in either an aerobic or anaerobic environment.

The biological treatment of many food processing wastes often lacks necessary nutrients within the waste to sustain desirable biological growth. Nutrient, nitrogen and phosphorus, addition may be required for effective treatment of cane sugar refining wastes. This could be economically achieved by the addition of nutrient-rich wastes from another source for combined treatment.

A discussion of the various methods of biological treatment is presented in the following paragraphs.

Activated Sludge. In this case the active biota is maintained in suspension in the waste water. Air, supplied to the system by mechanical means, mixes the reaction medium and supplies the microorganisms with the oxygen required for their metabolism. The microorganisms grow and feed on the nutrients in the inflowing waste waters. There are fundamental relationships between the growth of these microorganisms and the efficiency of the system to remove BOD_5.

A number of activated sludge systems have been designed, all of which have their own individual configurations. Basically, these designs consist of some type of pretreatment, usually primary sedimentation, followed by aeration, and by secondary sedimentation which allows the sludge produced to separate, leaving a clear effluent. Portions of the settled sludge are recirculated and mixed with the influent to the aeration section, usually at a proportion ranging from between 10 to 100 percent, depending upon the specific modification to the basic activated sludge process.

The goal of these plants is to produce an actively oxidizing microbial population which will also produce a dense "biofloc" with excellent settling characteristics. Usually, an optimization of floc growth and overall settleability is necessary since very active microbial populations do not always form the best flocs.

The extended aeration modification of the activated sludge process is similar to the conventional activated sludge process, except that the mixture of activated sludge and raw materials is maintained in the aeration chamber for longer peiods of time. The common detention time in extended aeration is one to three days, rather than the six hours detention time common to conventional activated sludge systems. During this prolonged contact between the sludge and raw wastes, there is ample time for organic matter to be adsorbed by the sludge and also for the organisms to metabolize the removal of organic matter which has been built up into the protoplasm of the organism. Hence, in addition to high organic removals from the waste waters, substantial decomposition of the organic matter of the microorganisms into stable products may occur and consequently less sludge will have to be handled.

In extended aeration, as in the conventional activated sludge process, it is necessary to have a final sedimentation tank. Some of the solids resulting from extended aeration are rather finely divided and settle slowly, therefore requiring a longer period of settling.

Activated sludge in its various forms is an attractive alternative for the treatment of cane sugar refining waste waters. Conventional design criteria are not directly transferable from municipal treatment applications. However, high levels of treatment efficiency are possible at the design loadings normally employed in treating other types of high strength organic wastes.

Within other industrial point source categories, such as the fruit and vegetable processing industry, activated sludge treatment plants are capable of removing 95 percent or better of the influent BOD_5 based upon proper nutrient addition, design, and operation. The general experience has been that biological solids separation problems can be avoided if the dissolved oxygen concentration remains above zero throughout the aeration basin, if strong, highly concentrated waste releases are minimized through proper management practices, and if sufficient amounts of nitrogen are present to maintain a critical nitrogen-to-BOD_5 ratio.

Activated sludge systems require less room than other high reduction biological systems, but have higher capital and operating costs. It is felt that properly designed and operated systems are capable of treating cane sugar refining waste waters to achieve high reductions of BOD.

Biological Filtration (Trickling Filtration). The purpose of the biofilter system is to change soluble organic wastes into insoluble organic matter primarily in the form of bacteria and other higher organisms. As the filter operates, portions of the biological growth slough off and are discharged as humus with the filter effluent. Usually, some physical removal system is required to separate this insoluble organic material which can be treated by other suitable methods, usually anaerobic fermentation in a sludge digestor.

Trickling filters are usually constructed as circular beds of varying depths containing crushed stone, slag, or similar hard insoluble materials. Liquid wastes are distributed over this bed at a constant rate and allowed to "trickle" over the filter stones. Heavy biological growths develop on the surface of the filter "media" throughout the depth of the filter and also within the interstitial spaces.

The biological film contains bacteria, (Zooglea, Sphaerotilus, and Beggiatoa); fungi (Fusarium, Geotrichum, Sepedonium); algae, both green and blue-green (Phormidium, Ulothrix, Mononostrona); and a very rich fauna of protozoa. A grazing fauna is also present on these beds consisting of both larval and adult forms of worms (Oligochaeta), insects (Diptera and Coleoptera among others), and spiders and mites (Arachnida).

A common problem with this type of filter is the presence of flies which can become a severe nuisance. Insect prevention can usually be prevented by chlorinating the influent or by periodically flooding the filter.

Recirculation of waste water flows through biological treatment units is often used to distribute the load of impurities imposed on the unit and stabilize the applied flow rates. Trickling filter BOD5 removal efficiency is affected by temperature and the recirculation rate. Trickling filters perform better in warmer weather than in colder weather. Recirculation of effluent increases BOD5 removal efficiency as well as keeping reaction type rotary distributers moving, the filter media moist, organic loadings relatively constant, and increasing contact time with the biological mass growing on the filter media.

Furthermore, recirculation improves distribution, equalizes effluent flow rates, obstructs entry and egress of flies, freshens incoming and applied waste waters, reduces the chilling of filters, and reduces the variation in time of passage through the secondary sedimentation unit.

Trickling filter BOD5 removal efficiency is inversely proportional to the BOD5 surface loading rate; that is, the lower the BOD5 applied per surface area, the higher the removal efficiency.

Other Aerobic Processes. Aerated lagoons use either fixed mechanical turbine-type aerators, floating propellor-type aerators, or a diffused air system for supplying oxygen to the waste water. Aerated lagoons can rapidly add dissolved oxygen to convert anaerobic waste waters to an aerobic state, providing additional BOD5 reduction, and require a relatively small amount of land. The system thus approaches conditions similar in nature to extended aeration without the recycle of sludge.

Disadvantages of this system are the high power requirements and the small reductions in suspended solids attained. Aerated lagoons generally do not reduce BOD5 and suspended solids adequately to be used as the final stage of a high performance biological treatment system. Aerated lagoons usually act as the final stage of secondary treatment and are followed by aerobic lagoons which capture suspended solids and afford further BOD5 reduction.

Aerobic ponds are large surface area, shallow lagoons, designed for nigh detention times; thus, they require large areas of land. Aerobic lagoons serve a three-fold function in waste reduction: they allow solids to settle out, equalize and control flow, and permit the stabilization of organic matter by aerobic and facultative microorganisms and also by algae.

Algae growth is common in aerobic lagoons and represents a drawback when aerobic lagoons are used for final treatment, in that algae may escape into the receiving waters. Algae in the lagoon, however, play an important role in stabilization. They utilize CO_2, sulfates, nitrates, phosphates, water, and sunlight to synthesize their own organic cellular matter and give off free oxygen. The oxygen may then be used by other microorganisms for their metabolic processes. However, when algae die they release their organic matter in the lagoon, causing a secondary loading.

Advantages of aerobic lagoons are that they reduce suspended solids, oxidize organic matter, and permit flow control and waste water storage. Disadvantages are the large amounts of land required, the algae growth problem, and odor problems.

Aerobic lagoons usually are the last stage in secondary treatment and frequently follow anaerobic or aerated lagoons. Large aerobic lagoons allow plants to store waste water discharges during periods of high flow or to store for irrigation. These lagoons are particularly popular in rural areas where land is available and relatively inexpensive.

Anaerobic Processes. Anaerobic or facultative microorganisms, which function in the absence of dissolved oxygen, break down organic wastes to intermediates such as organic acids and alcohols. Methane bacteria then convert the intermediates primarily to carbon dioxide and methane, and where sulfur compounds are present, to hydrogen sulfide. Anaerobic processes are economical because they provide high overall removal of BOD_5 and suspended solids with no power cost (other than pumping) and with low land requirements. Two types of anaerobic processes are possible: anaerobic lagoons and anaerobic contact systems.

Anaerobic lagoons may be used as the first step in secondary treatment. These are relatively deep, low surface area systems, with several days of detention time.

Plastic covers of nylon-reinforced Hypalon, polyvinyl chloride, and styrofoam can be used to retard heat loss, to ensure anaerobic conditions, and to retain obnoxious odors. Properly installed covers provide a convenient method for collection of methane gas.

Influent waste water flow should be near, but not on, the bottom of the lagoon. In some installations, sludge is recycled to ensure adequate anaerobic seed for the influent. The effluent discharge point should be located to prevent short-circulating of the influent stream and to prevent carry-over of the scum layer.

Advantages of an anaerobic lagoon system are initial low cost, ease of operation, and the ability to handle shock waste loads and yet continue to provide a consistent quality effluent. The major disadvantage of an anaerobic lagoon is potential odor problems although odors are not usually a serious problem at well managed lagoons.

Anaerobic lagoons used as the first stage in secondary treatment are usually followed by aerobic lagoons. Placing a small, mechanically aerated lagoon between the anaerobic and aerobic lagoons is another alternative.

The anaerobic contact system requires far more equipment for operation than do anaerobic lagoons, and consequently is not as commonly used. The equipment consists of equalization tanks, digesters with mixing equipment, air or vacuum gas stripping units, and sedimentation tanks (clarifiers). Equalized waste water flow is introduced into a mixed digester where anaerobic decomposition takes place; detention times of three to twelve hours are common. After gas stripping, the digester effluent is clarified and the sludge partially recycled.

Advantages of the anaerobic contact system are: high organic waste load reduction in a relatively short time, production and collection of methane gas that can be used to maintain a high temperature in the digester and also to provide auxilary heat and power, good effluent stability even at times of waste load shocks, and application in areas where anaerobic lagoons cannot be used because of odor or soil conditions. Disadvantages of anaerobic contractors are the high initial and maintenance costs and the potential of odor emissions from the clarifiers.

Advanced Treatment Systems

A discussion of advanced treatment methods is presented; these methods provide a means of further polishing the effluent from the biological treatment systems previously described. While an individual technology discussed may not of itself constitute a complete process, upon its addition to a treatment system it would become part of a complete treatment process.

Carbon Adsorption. The reduction of tastes and odors in water supplies by adsorption of the offending substances on activated carbon is probably the most important direct use of adsorption technology used in water treatment. Columns or beds of granular activated carbon are employed for concentrating organic pollutants from water for purposes of anlysis or for removal of the pollutants.

The fixed bed or countercurrent operation is the most effective and efficient way of using activated carbon. The influent comes into contact with the adsorbent along a gradient of mounting residual activity providing that the most active carbon gives a final polish to the effluent stream.

Partial regeneration of carbon by thermal volatilization or steam distillation of organic adsorbates is possible, but available regeneration procedures will have to be improved or new ones invented if adsorption is to become a widely useful operation in water treatment. However, cane sugar refineries use multi-hearth furnaces to regenerate the bone char or granular activated carbon used as a decolorant of sugar liquor. This capability could minimize the difficulties and costs associated with regeneration of any activated carbon utilized in waste water treatment.

Granular activated carbon can replace other filtering materials in structures not unlike present-day rapid sand filters. Beds of granular activated carbon can, in fact, be made to perform as both filters and adsorbents. However, activated carbon filters must be somewhat deeper than sand filters, even though they may be operated at somewhat higher rates of flow per unit volume of bed. In this way, beds of spent granular activated carbon or bone char may be utilized to act as a polishing step to further remove biological solids resulting from the biological treatment of refinery waste waters.

Filtration. Two types of filtration will be considered in this discussion: (1) sand filtration, both slow and rapid, and (2) diatomaceous earth filtration.

A slow sand filter is a specially prepared bed of sand or other material fines on which doses of waste water are intermittently applied and from which the effluent is removed by an under-drainage system. The solids removal occurs mainly at the surface of the filter. BOD removal occurs primarily as a function of the degree of solids removal although some biological action occurs in the top inch or two of sand. Effluent from the sand filter is of a high quality with $BOD_{\underline{5}}$ and suspended solids concentrations very low.

Slow sand filters require larger land areas than rapid sand filter facilities; however, slow sand filters may operate long periods of time without cleaning, whereas rapid sand filters are usually cleaned by backwashing periodically.

Slow sand filters require no extra preparatory water treatment prior to filtration, although it is recommended. Rapid sand filters are designed to remove the solids remaining after treatment by coagulation, flocculation, and sedimentation. Construction costs of slow sand filters are relatively high due to the large area requirements; however, operating and maintenance costs are relatively low because slow sand filters may operate for long durations. Rapid sand filters have a relatively low construction cost due to low land requirements; however, operating and maintenance costs are relatively high as they cannot be operated for long periods of time without backwashing.

Rapid sand filters are subject to a variety of ailments such as cracking of the bed, formation of mud balls, plugging of portions of the bed, jet actions at the gravel-sand separation plane, sand bails, and sand leakage into the under-drainage systems. Usually these problems can be minimized or eliminated by proper design and plant operation. Sand filters are well noted for their efficient removal of bacteria, color, turbidity, and large microorganisms.

Diatomaceous earth filters have found use as: (1) mobile units for water purification and (2) stationary units for swimming pools and general water supplies. Skeletons of diatoms mined from deposits compose the diatomaceous earth. The filter medium is a layer of diatomaceous earth built upon a porous septum. The resulting pre-coat is supported by the septum, which serves also as a drainage system. Water is strained through the pre-coat unless the applied water contains so much turbidity that the unit will maintain itself only if additional diatomaceous earth, called body feed, is introduced into the incoming water to preserve the open texture of the layer. There are few known applications as yet in the food processing field.

Microscreening. Microsreening has been a viable solids-removal process for many years. A microsreen consists of a rotating drum with a screen or fabric constituting the periphery. Feedwater enters the drum internally and passes radially through the screen with the concomitant deposition of solids on the inner surface of the screen. At the top of the drum, jets of water are directed onto the screen to remove deposited solids. This backwash stream of dislodged solids and washwater is captured in a receiving hopper inside the drum and flows out through the hollow axle of the unit. In order to reduce slime growths on the screen, an ultraviolet lamp is continually operated in close proximity to the screen. The driving force for the system is the head differential between the inside and outside of the screen. As solids are removed on the screen a mat is formed which improves the solids removal efficiency and also results in increased head loss through the screen. The maximum head loss is usually limited to 0.15 meters (6 inches) in order to prevent screen damage. In order to prevent the limiting head loss from being exceeded, drum speed and wash water pressure are increased. In newer units, automatic controls handle these adjustments.

Individual studies have demonstrated the effects of a number of design, maintenance, and operational factors on the performance of microscreening units:

Design:

-- Approximately one-half of the applied screen wash water penetrates and is removed with the solids-bearing stream.

-- The solids-bearing waste stream is usually returned to the main treatment plant.

-- It is desirable to have gravity flow from the clarifier to the microscreener to avoid shearing of the more fragile solids.

-- Prechlorination should be avoided in order to protect the screen.

- Chloride concentrations exceeding 500 mg/l may cause corrosion problems.

- Microscreens do not successfully remove floc particles resulting from coagulation by chemicals such as aluminum sulfate.

Maintenance:

- Screens for the pressure washing system may tend to clog due to the presence of grease in the effluent.

- Most units require frequent cleaning with a hypochlorite solution which entails a few hours of removal from service in order to clean the fabric.

- High iron or manganese concentrations in the feed may necessitate an occasional acid wash of the screen to destroy the resulting film buildup.

Operation:

- Minimum drum speeds (consistent with head loss limitations) will give the greatest removal of suspended solids.

- Higher pressures are more beneficial with regard to the jet washing system than greater quantities of water.

- High solids loadings can cause severe reductions (of up to two-thirds of design capacity) in throughput as well as increasing acceleration of slime buildup.

Reverse Osmosis. Osmotic pressure acts as the driving force as water molecules pass through a semi-permeable membrane from a dilute to a concentrated solution in search of equilibrium. This natural response can be reversed by placing the concentrated solution under hydrostatic pressures higher than the osmotic pressure.

A good deal of experimentation has been carried out in an attempt to apply membrane processes including reverse osmosis, ultrafiltration, and electrodialysis to the treatment of industrial waste waters. Reverse osmosis has the capability of removing dissolved and suspended materials of both organic and inorganic nature from waste streams. However, organic-laden streams tend to foul reverse osmosis membranes resulting in substantially decreased throughput.

Recent developments of the spiral or hollow tube reverse osmosis systems permit large membrane areas to be incorporated into a small space, thus permitting large volumes of water to be treated. The use of either the spiral or hollow tube system requires that all particles larger than 10 to 20 microns be removed from the waste stream before entering the reverse osmosis system.

Disadvantages of the reverse osmosis process are the relatively high costs of treatment when applied to large volumes of water, the potential of bacterial growth on or near the membrane and its damaging effect on the membrane, and the sensitivity of the reverse osmosis units to both alkaline and high temperature fluids. Chlorine can damage the presently available membranes; therefore, the chlorination of water cannot occur before the reverse osmosis step.

Ultrafiltration. Ultrafiltration utilizes a membrane process similar to reverse osmosis for the removal of contaminants from water. Unlike reverse osmosis, ultrafiltration is not impeded by osmotic pressure and can be effected at low pressure differences. The molecular weight range of materials that might be removed by ultrafiltration is from 500 to 500,000. This would remove such materials as some microorganisms, starches, gums, proteins, and clays. Ultrafiltration is finding applications in the food industry in sugar purification, whey desalting, and fractionation. It can be used as a substitute for thickeners, clarifiers, and flocculation in waste water treatment. In addition to removal of the above contaminants from waste water, it can also be applied to sludge dewatering.

At the present time, because of high capital and operating costs, this system has not found acceptance in the treatment of waste effluents.

Ultimate Disposal Methods

Percolation and Evaporation Lagoons. The liquid portion of cane sugar refining wastes can be "completely" treated in percolation and evaporation lagoons. These ponds can be sized according to the annual flow, so that the inflow plus the incidentally added water are equal to percolation and evaporation losses. There is, theoretically, no surface outflow in the usual sense.

Biological solids grown in the pond can be a major operating problem. The soil interstices can become biologically sealed, causing percolation rates to be greatly diminished. Unless corrective action is taken, the pond may become largely an evaporation lagoon. To prevent this, annual scarification and solids removal might be required.

There are two major objections to percolation-evaporation ponds. The first is that under almost any loading conditions the ponds may turn septic, with odor problems resulting. Secondly, there is the potential for long-range damage to aquifers, since objectionable and biologically resistant organics may be carried into the groundwater by continuous percolation.

Spray Irrigation. Spray irrigation is another method currently utilized in the sugar industry for disposal of waste waters. The design of such systems is rapidly becoming a highly scientific operation. Numerous cases of both unsatisfactory results and trouble-free experience have been encountered with the application of this technology. Such systems should be designed with a great deal of flexibility to handle unforeseen problems. The hydraulic and organic characteristics of the soil profile as well as the rates of waste degradation must be considered in design. The need to properly balance nutrient loads to ensure adequate microbiological activity and adequate growth of plants without undue losses of nutrients to groundwater must be considered. Other important design considerations include crop management insuring proper crops and crop sequences and climatic conditions considering evapotranspiration rates, precipitation, and cold weather operation.

Spray irritation consists essentially of spraying the liquid waste on a field at as high a rate and with as little accompanying nuisances or difficulties of operation as possible. Pretreatment of waste water to remove solids may be necessary in order to prevent clogging of the spray nozzles.

Waste water disseminated by spray irrigation percolates through the soil and the organic matter in the waste undergoes a biological degradation. The liquid in the waste stream is either stored in the soil or leached to a groundwater. Approximately 10 percent of the waste flow will be lost by evapotranspiration (the loss due to evaporation to the atmosphere through the leaves of plants).

Spray irrigation presents an ideal method for disposal of liquid wastes when a combination of suitable features exists. These features include:

-- A large area of relatively flat land available at an economical price.

-- Proximity of the disposal area to the plant site.

-- Proper type of soil to promote optimum infiltration.

-- Absence of a groundwater underlying or nearby the disposal area which is being or could be used as a public water supply.

-- Absence of suspended matter in the waste water of such a nature as to cause clogging of the spray nozzles.

-- Proper combination of climatic conditions conducive to cover crop growth, percolation and evaporation, i.e., sunny and relatively dry climate.

In actual practice, waste waters (after adequate screening) are usually retained in a "surge tank" of sufficient volume to provide continuous operation of sprays. The impounded screened waste is pumped to a header pipe and to a series of lateral aluminum or lightweight lines under ample pressure to provide each sprinkler with similar volumes of waste water for application to the land.

The amount of waste water reaching groundwater is variable in quantity and rather difficult to predict. In some cases it might be expected that no usable groundwater would be involved. Considerable study seems to be needed in evaluating this potential problem.

The following factors must be evaluated in designing a land disposal system:

- The site should be relatively level and well covered with vegetation.
- The soil should be light in texture and have a high sand or gravel content. Some organic matter may be beneficial, but high clay content is detrimental.
- Spray testing and soil analysis prior to full-scale irrigation is recommended.
- Soil cultivation should be practiced to prevent compaction.
- Ground water levels at the spray site should be at least 10 feet below the surface to allow for proper decomposition of the waste as well as for more rapid percolation.

With the proper equipment and controlled application of the waste, spray irrigation will completely prevent stream pollution, will not create odor problems, and is usually less expensive than other methods of waste disposal. The amount of land required may not, at present, be reliably predetermined. Different cover crops and different types of soil will give varying infiltration rates.

Ultimate disposal systems may consist of a combination of lagooning and land disposal. In this type of system large ponds are constructed to receive the waste effluents. If odor becomes a problem because of location, sufficient aeration equipment must be provided to reduce or eliminate the odor. The waste effluent is removed from the pond or lagoon and directed to spray irrigation.

Soil fertility, crop production, and soil conservation considerations must of necessity be used as an ultimate basis for regulating land-spreading operations if the system is to remain continuously effective.

TREATMENT AND DISPOSAL TECHNOLOGY CURRENTLY EMPLOYED BY THE CANE SUGAR REFINING INDUSTRY

Waste water treatment and disposal in the cane sugar refining industry ranges from essentially no treatment to complete land retention with no discharge of waste water to surface waters. Since the early 1950's most large urban refineries have discharged major process waste streams, such as char wash, to municipal sewers. The current standard practice for urban refineries, which represent approximately three-fourths of American refined cane sugar production, is to discharge all waste streams other than barometric condenser cooling water to municipal sewage treatment plants. Rural refineries, representing the remaining one-fourth of total sugar production, generally have available land for impoundment, and the standard practice of these refineries is either total or partial waste water retention.

There are two notable exceptions to the general practice of urban refineries discharging process water to municipal sewers and barometric condenser cooling water to surface water bodies. One large crystalline refinery, which utilizes a cooling tower for recirculation of barometric condenser cooling water, discharges all waste water except uncontaminated (non-contact) cooling water to municipal treatment. This is possible through the use of a cooling tower recycle system which reduces barometric condenser cooling water discharge by 98 percent (ultimately this system is expected to reduce the discharge of barometric condenser cooling water by 99 percent).

The second exception is a small liquid refinery which uses municipal water for barometric condenser cooling water intake. Unlike other refineries that use low quality surface water for barometric condenser cooling water, this refinery is able to extensively re-use the barometric condenser cooling water effluent in-plant, and discharges all waste water to municipal treatment. It must be noted, however, that this refinery does not employ affination, does not have vacuum pans, and, therefore, uses an atypically small flow of barometric condenser cooling water.

The following table, Table 17, is a summary of the existing waste treatment practices of the refineries currently operating. All cane sugar refineries are represented and the most reliable and current information presented.

Biological treatment of sugar wastes has been demonstrated to a limited extent in the raw cane sugar industry and more extensively outside of the industry. Sucrose is well known to be highly biodegradable, and substantial BOD_5 reductions have been observed in impoundage lagoons for treatment of waste waters from combined factory-refineries. In the beet sugar industry, anaerobic and aerobic fermentation processes have been successfully used (17). The applicability of biological treatment to refinery waste waters has also been well demonstrated by the 12 refineries that discharge process wastes to municipal biological treatment systems. While no refineries currently employ biological treatment in the form of activated sludge or aerated lagoons, these systems are considered to be currently available technology for the industry. With proper design and with nutrient addition to the nutrient deficient wastes, these systems can achieve 90 to 95 percent and higher treatment efficiencies for highly organic wastes such as process waste water from cane sugar refining.

Waste holding lagoons have widespread use in the raw cane sugar industry and are employed by several cane sugar refineries in rural areas. One small liquid refinery was at one time operated in conjunction with a raw

TABLE 17

SUMMARY OF WASTE WATER TREATMENT AND DISPOSAL TECHNIQUES OF UNITED STATES CANE SUGAR REFINERIES

Refinery	Disposal of Waste Waters
C-1	All process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake after regeneration and recycle of filter aid.
C-2	All process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake after regeneration and recycle of filter aid.
C-3	All liquid wastes to river. Filter slurry to river.
C-4	All process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake after regeneration and recycle of filter aid.
C-5	All process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake.
C-6	All liquid wastes to river. Dry haul filter cake. Future use of municipal system is probable.
C-7	Primary settling of process water; overflow discharges to river.
C-8	All liquid wastes to river. Future use of municipal system is probable (sewer hook-up is in-place). Dry haul filter cake.
C-9	Most process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake.
C-10	Most process water to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake.

TABLE 17

SUMMARY OF WASTE WATER TREATMENT AND DISPOSAL TECHNIQUES OF UNITED STATES CANE SUGAR REFINERIES (CONTINUED)

Refinery	Disposal of Waste Waters
C-11	Discharge into a swamp after traveling through a two and a half mile canal. Have recently constructed a spray pond. Recycle of barometric condenser cooling water is a possibility.
C-12	Total impoundment of waste water resulting in no discharge to navigable waters. Have two cooling towers for recycle of barometric condenser cooling waters; blowdowns are .3 and .7 percent.
C-13	Discharges into a swamp.
C-14	All process wastes to municipal sewers; recycle of barometric condenser cooling water through a cooling tower and discharge of blowdown to municipal sewers. Dry haul filter cake.
L-1	All liquid wastes to municipal sewers. Filter slurry to municipal sewer.
L-2	All process water to municipal sewer; barometric condenser cooling water to river. Filter slurry to settling, dewatering, and dry haul.
L-3	All process water to municipal sewer; barometric condenser cooling water to river. Filter slurry to sewer.
L-4	Total impoundment of waste waters resulting in no discharge to navigable waters. Barometric condenser cooling water recycled through a spray canal. Filter slurry to total impoundage.
L-5	Barometric condenser cooling water recycled through a cooling tower. Process water and filter slurry discharged with no treatment.

TABLE 17

SUMMARY OF WASTE WATER TREATMENT AND DISPOSAL TECHNIQUES OF UNITED STATES CANE SUGAR REFINERIES (CONTINUED)

Refinery	Disposal of Waste Waters
CL-1	Most process water to municipal sewers; barometric condenser cooling water to river. Filter slurry dewatered and dry hauled.
CL-2	Most of process wastes to municipal sewers; barometric condenser cooling water to river. Dry haul filter cake.
CF-1	Closed system of canals and holding ponds resulting in no discharge to navigable waters. Filter slurry to total impoundage. Barometric condenser cooling water recycled through a spray pond.
CF-2	Total impoundment of acid/caustic wastes and filter cake slurry; impoundment with overflow of all other waste waters, 700 acres of lagoons.
CF-3	Barometric condenser cooling water passed through spray pond (partial recycle, 75-90%, possible) before discharge; all process waters discharge to total impoundage. Filter slurry to total impoundage.
CF-4	Barometric condenser cooling impounded, then discharged; all other waters impounded completely in ponds; cooling tower recently built (50% of condenser water); recycle possible. Filter slurry to total impoundage.
CF-5	Partial impoundment.
CF-6	Partial reuse of waste waters in raw sugar factory for cane washing during grinding season.
CF-7	Partial impoundment.
CF-8	Partial impoundment.

sugar factory, and a lagoon system was designed to contain all wastes from both operations. The subsequent closing of the factory left the refinery with more than adequate pond area for total waste water impoundage. Several factory-refinery combinations in Louisiana, Florida, and Puerto Rico use impoundage to various extents; two refineries discharge to large, swampy, private land holdings with a resulting undefined eventual discharge.

Those refineries which utilize waste holding ponds to achieve impoundage with an overflow are those operating in conjunction with raw cane sugar factories. Wastes from both the refinery and the factory are discharged to the same holding ponds, making it impossible to determine the treatment efficiency associated with the application of this technology to refinery waste waters alone.

In the construction and operation of holding ponds, sealing of pond bottoms to control percolation may be necessary (although expensive), but self sealing may occur as a result of organic mat formation. No contamination of groundwater should be allowed.

Land irrigation is practiced at only one refinery - a small refinery in Puerto Rico which is located on the dry south coast of the island. Other refineries are prohibited from using this technology by either (1) being located in urban areas, or (2) being located in areas of high rainfall.

Deep-well injection is not practiced in cane sugar refining nor in beet sugar processing; one raw cane sugar factory in Florida practices this method of disposal. Deep-well injection may exist as a disposal alternative; however, the effects of subsurface injection are usually difficult to determine. This method of disposal can only be recommended with the stipulation that extensive studies be conducted to insure environmental protection beyond any reasonable doubt.

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

COST AND REDUCTION BENEFITS OF ALTERNATIVE TREATMENT AND CONTROL TECHNOLOGIES FOR CANE SUGAR REFINERIES

The Model Refineries

Assumptions Pertaining to Water Usage, Raw Waste Loading, and Alternatives of Control and Treatment

For the purpose of establishing effluent limitations guidelines, model refineries were hypothesized to represent the crystalline and liquid cane sugar refining industry subcategories. These model refineries were derived from a basis of average water usage and conservation, but average to poor in-plant controls to limit BOD_5 and suspended solids loadings. These model refineries are illustrated in Figures 18 and 19. The following treatment alternatives have been applied to these model refineries to determine the best practicable control technology currently available (BPCTCA), the best available technology economically achievable (BATEA), and the standards of performance for new sources (NSPS):

Alternative A: This Alternative represents the baseline and includes good water usage but poor in-plant controls. This Alternative also assumes no treatment, and represents the model raw waste loadings.

Alternative B: This Alternative involves the elimination of a discharge of filter cake, which results from the clarification of melt liquor. Filter cake can be disposed of without discharge to navigable waters by controlled impoundage of the filter slurry (Alternative B-1) or by dry handling of the filter cake (Alternative B-2). A decrease in water usage of 0.25 cubic meters per metric ton (60 gallons per tons) of melt is evidenced over Alternative A if dry handling of filter cake is incorporated.

Alternative C: This Alternative involves, in addition to Alternative B, the addition of demisters and external separators to reduce entrainment of sucrose into barometric condenser cooling water. This technology is illustrated for both liquid and crystalline refineries in Figures 20 and 21. For the barometric condenser cooling water flows developed for both the crystalline and liquid cane sugar refining subcategories, BOD_5 entrainment can be reduced to below 10 mg/l.

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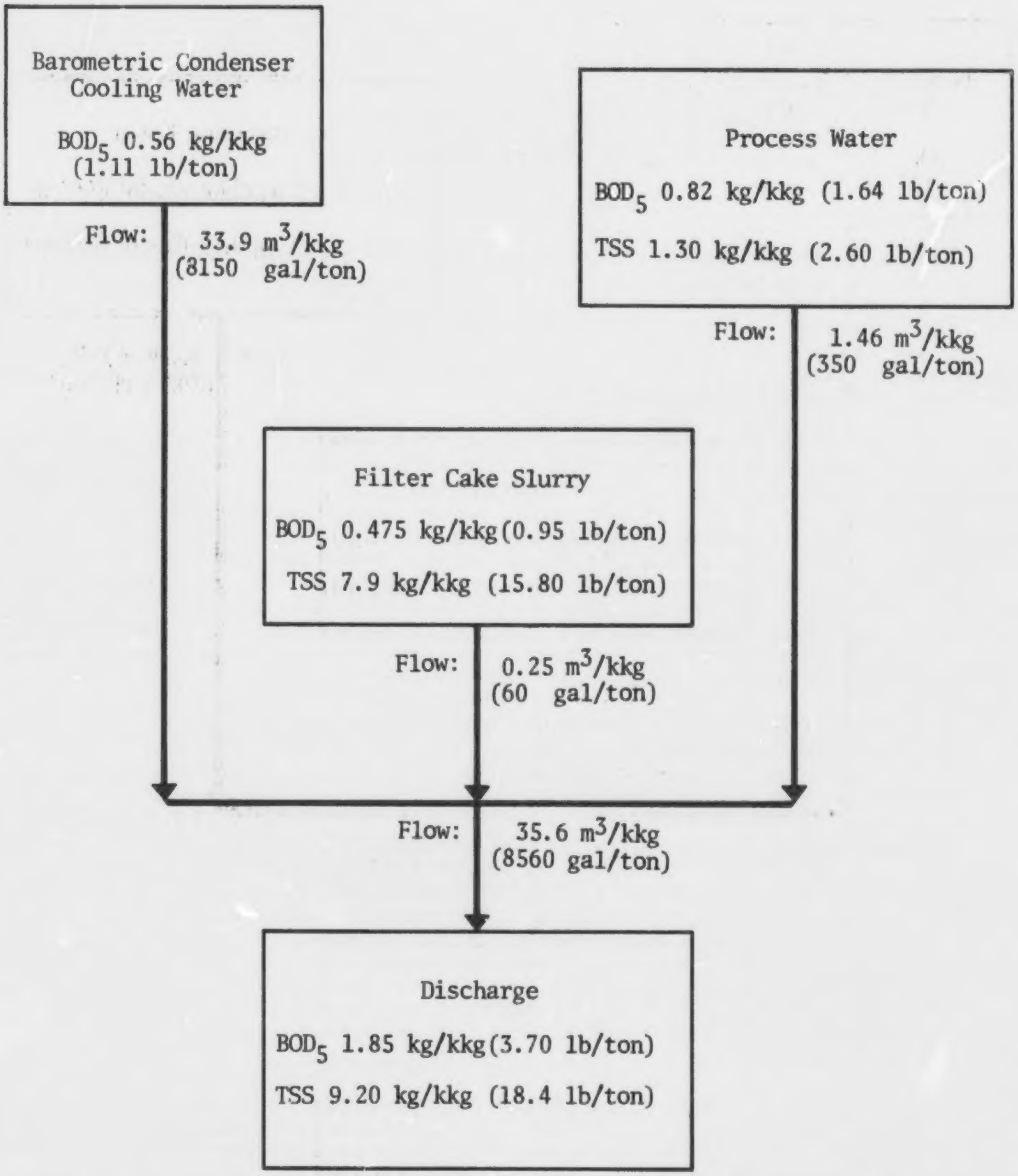
Barometric Condenser Cooling Water
BOD$_5$ 0.56 kg/kkg (1.11 lb/ton)
Flow: 33.9 m^3/kkg (8150 gal/ton)
Process Water
BOD$_5$ 0.82 kg/kkg (1.64 lb/ton)
TSS 1.30 kg/kkg (2.60 lb/ton)
Flow: 1.46 m^3/kkg (350 gal/ton)
Filter Cake Slurry
BOD$_5$ 0.475 kg/kkg (0.95 lb/ton)
TSS 7.9 kg/kkg (15.80 lb/ton)
Flow: 0.25 m^3/kkg (60 gal/ton)
Flow: 35.6 m^3/kkg (8560 gal/ton)
Discharge
BOD$_5$ 1.85 kg/kkg (3.70 lb/ton)
TSS 9.20 kg/kkg (18.4 lb/ton)

Figure 18

ESTIMATED RAW WASTE LOADINGS AND WATER USAGE
FOR THE MODEL CRYSTALLINE CANE SUGAR REFINERY

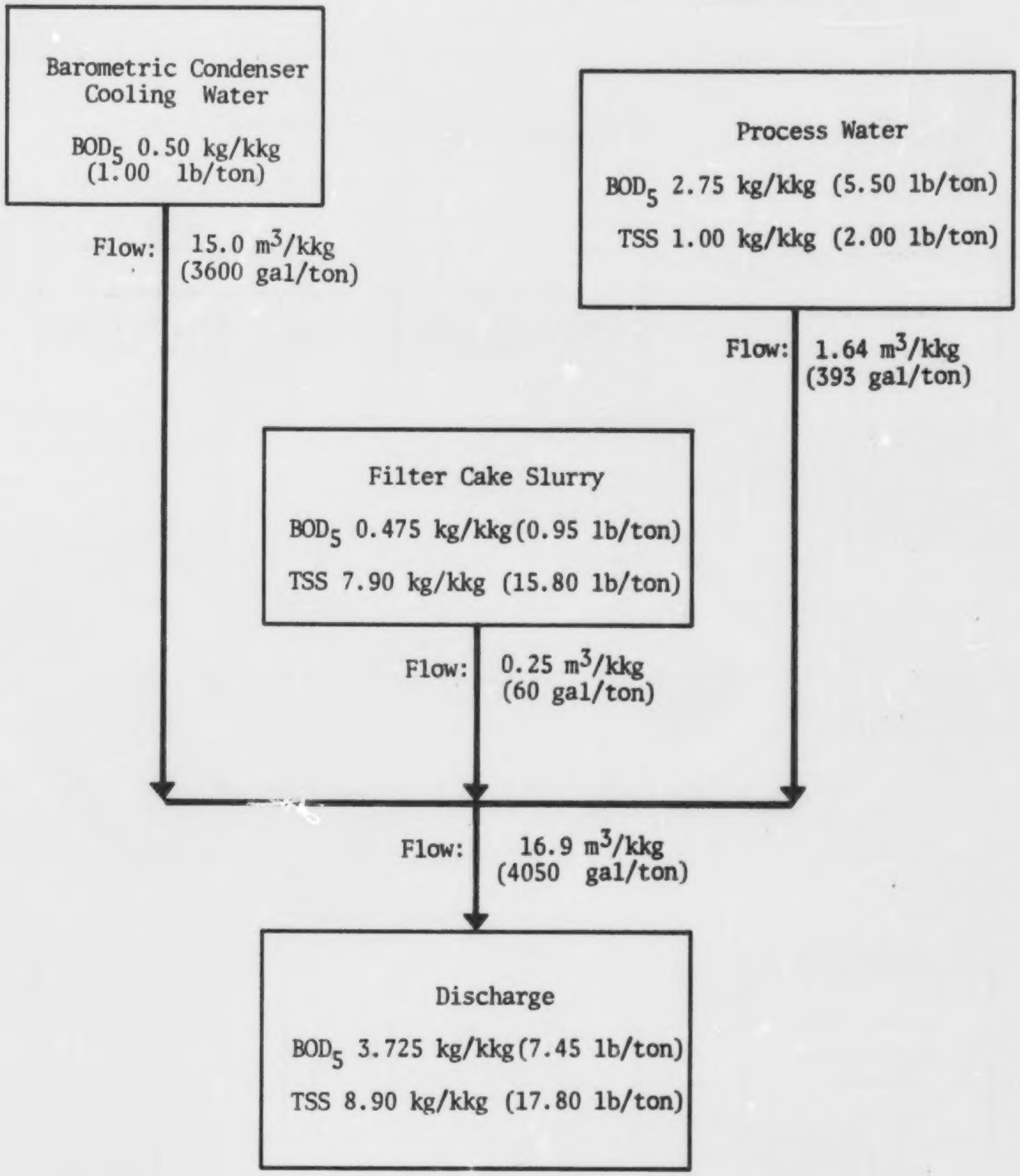
Barometric Condenser Cooling Water
BOD_5 0.50 kg/kkg (1.00 lb/ton)
Flow: 15.0 m^3/kkg (3600 gal/ton)
Process Water
BOD_5 2.75 kg/kkg (5.50 lb/ton)
TSS 1.00 kg/kkg (2.00 lb/ton)
Flow: 1.64 m^3/kkg (393 gal/ton)
Filter Cake Slurry
BOD_5 0.475 kg/kkg (0.95 lb/ton)
TSS 7.90 kg/kkg (15.80 lb/ton)
Flow: 0.25 m^3/kkg (60 gal/ton)
Flow: 16.9 m^3/kkg (4050 gal/ton)
Discharge
BOD_5 3.725 kg/kkg (7.45 lb/ton)
TSS 8.90 kg/kkg (17.80 lb/ton)

Figure 19
ESTIMATED RAW WASTE LOADINGS AND WATER USAGE
FOR THE MODEL LIQUID CANE SUGAR REFINERY

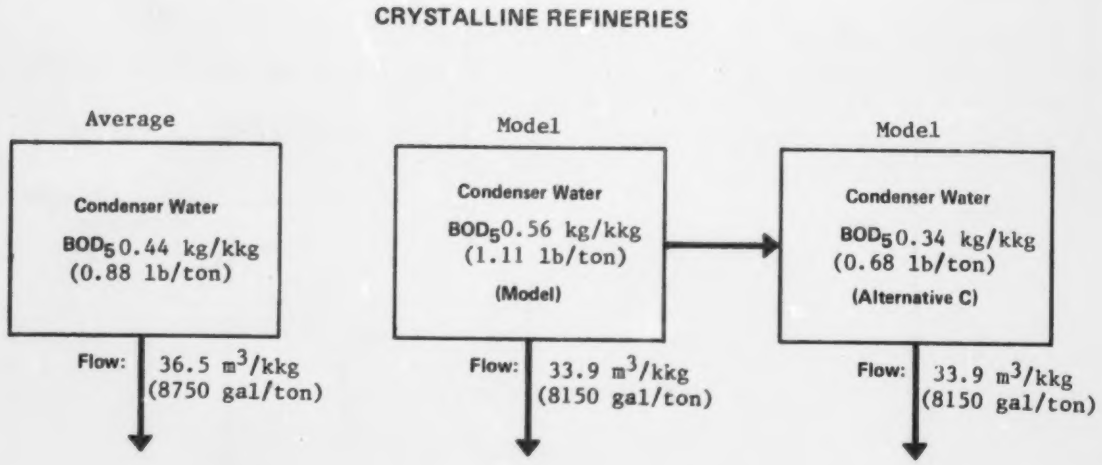
CRYSTALLINE REFINERIES
Average
Condenser Water
BOD5 0.44 kg/kkg
(0.88 lb/ton)
Flow: 36.5 m3/kkg
(8750 gal/ton)
Model
Condenser Water
BOD5 0.56 kg/kkg
(1.11 lb/ton)
(Model)
Flow: 33.9 m3/kkg
(8150 gal/ton)
Model
Condenser Water
BOD5 0.34 kg/kkg
(0.68 lb/ton)
(Alternative C)
Flow: 33.9 m3/kkg
(8150 gal/ton)

Figure 20
CONDENSER WATER LOADINGS AND WATER USAGE FOR CRYSTALLINE CANE SUGAR REFINERIES

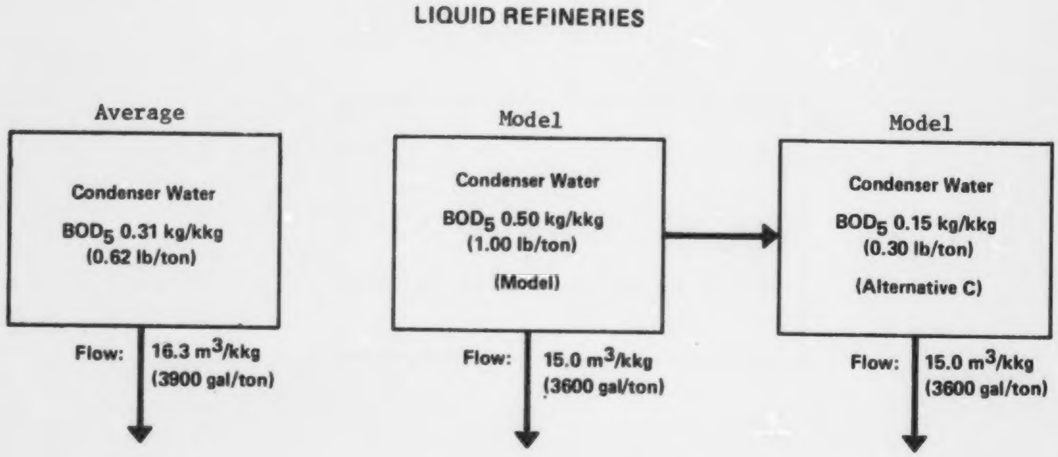
LIQUID REFINERIES
Average
Condenser Water
BOD5 0.31 kg/kkg
(0.62 lb/ton)
Flow: 16.3 m3/kkg
(3900 gal/ton)
Model
Condenser Water
BOD5 0.50 kg/kkg
(1.00 lb/ton)
(Model)
Flow: 15.0 m3/kkg
(3600 gal/ton)
Model
Condenser Water
BOD5 0.15 kg/kkg
(0.30 lb/ton)
(Alternative C)
Flow: 15.0 m3/kkg
(3600 gal/ton)

Figure 21
CONDENSER WATER LOADINGS AND WATER USAGE FOR LIQUID CANE SUGAR REFINERIES

Alternative D: This Alternative involves, in addition to Alternative C, the addition of an activated sludge system to treat process waters.

Alternative E: This Alternative involves, in addition to Alternative D, the recycle of barometric condenser cooling water through a cooling device with biological treatment of the assumed two percent blowdown and incorporates sand filteration of the effluent from the activated sludge system to further effect solids removal. This results in reductions in water usages of 88 percent for liquid refineries and 94 percent for crystalline refineries, over Alternative D.

Alternative F: This Alternative includes, in addition to Alternative C, the elimination of a discharge of process waters by total impoundage of this waste stream. This technology requires that large quantities of land be available and is not judged to be available technology for urban refineries. It is a current practice of many rural refineries, however.

Alternative G: This Alternative involves in addition to Alternative F, a recycling of barometric condenser cooling water through a cooling device and total retention of the assumed two percent blowdown. This technology requires that large quantities of land be available and is not judged to be available technology for urban refineries. It is a current practice of three refineries, all rurally located. Reduction in water usages of 88 percent for liquid refineries and 94 percent for crystalline refineries results, over Alternative F.

Assumptions Pertaining to the Cost of Control and Treatment Alternatives

The cost estimates contained in this document are based on two crystalline refineries with melts of 545 metric tons (600 tons) per day and 1900 metric tons (2100 tons) per day, respectively, and a liquid refinery with a melt of 508 metric tons (560 tons) per day. These refineries are considered to be generally representative of both large and small crystalline operations and of liquid operations. Obviously, any given existing installation may vary considerably from the models presented; each sugar refinery has unique characteristics and unique problems that must be taken into consideration. The following are assumed features of the representative refineries:

1. The present level of barometric condenser cooling water BOD_5 entrainment is 16 ppm in crystalline refineries and 33 ppm in liquid refineries.
2. Both liquid and crystalline refineries employ liquid level controls on evaporators and absolute pressure controls on the last evaporator body.

3. Both crystalline refineries employ triple-effect evaporators; the liquid refinery uses double-effect evaporators.
4. Total mud slurry equals 114 cubic meters (30,000 gallons) per day for the liquid refinery, 135 cubic meters (35,700 gallons) per day for the 545 metric ton (600 ton) per day crystalline refinery, and 455 cubic meters (120,000 gallons) per day for the 1900 metric ton (2100 ton) per day crystalline refinery.
5. The operating year consists of 250 days.
6. Ninety-eight percent of condenser water BOD_5 is due to sucrose.
7. Both liquid and crystalline refineries discharge diatomaceous earth filter slurries.
8. The liquid and crystalline refineries do not recycle condenser water.
9. There is presently a discharge of process water with no treatment in the case of both liquid and crystalline refineries.

Basis of Cost Analysis

The following are the basic assumptions made in the presentation of cost information:

1. Investment costs are based on actual engineering cost estimates.
2. 0.454 kg (one lb.) of sugar is equivalent to .511 kg (1.125 lb.) of BOD_5.
3. 3.79 liters (one gallon) of 80° Brix final molasses sells for $.042 per liter ($.16 per gallon).
4. All costs are August 1971 dollars.
5. Equipment depreciation is based on an 18 year straight-line method, except for rolling stock which is depreciated over 6 years by the straight-line method.
6. Excavation of filter mud pits costs $0.53 per cubic meter ($.40 per cubic yard); annual excavation and disposal costs $0.79 per cubic meter ($0.60 per cubic yard).
7. Annual interest rate for capital cost equals 8 percent.
8. Salvage value for all facilities depreciated over 18 years is zero.
9. Only sugar losses in the barometric condenser cooling water can be recovered.
10. Liquid sugar sells for $254.00 per metric ton ($230.50 per ton); crystalline sugar sells for $260.00 per metric ton ($236.40 per ton).
11. Contingency is taken at 10 percent of installed cost.
12. Engineering and expediting costs are taken at 10 percent of installed cost plus contingency.
13. Total yearly cost equals:
    (Investment cost) . (Yearly depreciation percentage) + Yearly operating cost + (Investment cost /2) (.08)

14. Hook-up charges associated with disposal to municipal systems are assumed to be zero.

Qualifying Statements. The following cost analyses include in some cases considerable costs for excavation and dyke construction. In some instances these costs may be minimized or nullified by topographic conditions. In other instances they may be reduced by utilizing in-house equipment and labor.

Land costs vary widely. The figures used herein are considered to be representative of non-urban areas where the use of land would be expected. In urban areas land is often not available; when it is used, the cost can be expected to be substantially higher than reported in this document.

The investment cost associated with hook-up to a municipal waste system is assumed herein to be nil. In actuality this cost can vary from zero to considerable sums of money; for purposes of economic impact, it is necessary to assess the cost on an individual basis. However, for the purpose of presenting cost information for the cane sugar refining industry, it must be noted that thirteen refineries already have municipal hook-up. Therefore, for these thirteen refineries, the assumption of zero additional cost is valid because they already have municipal hook-up.

Crystalline Refining

Two representative crystalline refineries were chosen as a basis for cost estimates: a small refinery with a melt of 545 metric tons (600 tons) per day and a large refinery with a melt of 1900 metric tons (2100 tons) per day. The following treatment alternatives may be applied to both refineries.

Alternative A: No Waste Treatment or Control. The effluent from a 545 metric ton (600 ton) per day crystalline refinery is 19,900 cubic meters (5.14 million gallons) per day and from a 1900 metric ton (2100 tons) per day crystalline refinery is 68,000 cubic meters (18.0 million gallons) per day. The resulting BOD_5 and suspended solids loads are 1.85 kilograms per metric ton (3.70 pounds per ton) and 9.20 kilograms per metric ton (18.40 pounds per ton) respectively, for both refineries. Since no waste treatment is involved, no cost associated with waste treatment or control can be attributed to this Alternative.

COSTS: 0
REDUCTION BENEFITS: None

Alternative B: Elimination of Discharge from Filters. This Alternative can be achieved either by impounding the mud resulting from slurrying filter cake with water or by dry hauling the desweetened filter cake to landfill. The resulting effluent waste loads for BOD_5 and suspended solids are 1.375 kilograms per metric ton (2.75 pounds per ton) of melt and 1.30 kilograms per metric ton (2.60 pounds per ton) of melt respectively, at this control level.

B-1: Impound Filter Slurry

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $33,000
Total Investment Cost: $33,000
Total Yearly Cost: $ 8,600

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $66,000
Total Investment Cost: $66,000
Total Yearly Cost: $20,000

B-2: Dry Disposal of Filter Cake

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $61,000
Total Investment Cost: $61,000
Total Yearly Cost: $45,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $61,000
Total Investment Cost: $61,000
Total Yearly Cost: $71,000

REDUCTION BENEFITS: An incremental reduction in BOD$_5$ of approximately 0.475 kilograms per metric ton (0.95 pounds per ton) of melt and in suspended solids of approximately 7.9 kilograms per metric ton (15.8 pounds per ton) of melt is evidenced over Alternative A. Total plant reductions of 25.7 percent for BOD$_5$ and 85.9 percent for suspended solids would be achieved.

For the purpose of accruing total costs in this section of the report, the use of dry disposal of filter cake (B-2) will be considered representative of Alternative B.

Alternative C: In plant Modifications to Reduce Entrainment of Sucrose into Condenser Water. This Alternative includes, in addition to Alternative B, the installation of demisters and external separators in order to reduce entrainment of sucrose in barometric condenser cooling water. It is assumed that, in addition, both refineries have good baffling and operational controls in the evaporators and vacuum pans, as well as good vapor height. This technology is currently widely practiced in the industry. The resulting effluent waste loads for BOD$_5$

and suspended solids are 1.16 kilograms per metric ton (2.32 pounds per ton) of melt and 1.30 kilograms per metric ton (2.60 pounds per ton) of melt respectively, for the selected refineries at this control level.

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $ 52,000
Total Investment Cost: $113,000
Total Yearly Cost: $ 62,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $ 73,000
Total Investment Cost: $134,000
Total Yearly Cost: $ 75,000

REDUCTION BENEFITS: An incremental reduction in BOD$_5$ of 0.22 kilograms per metric ton (0.44 pounds per ton) of melt is evidenced over Alternative B. The total reduction in BOD$_5$ is 37.3 percent. No further reduction in suspended solids is achieved.

Alternative D: Biological Treatment of Process Water. This Alternative assumes the addition of an activated sludge plant to Alternative C to treat process water. Presently there are no refineries which have their own biological treatment systems, but refinery wastes are commonly treated in municipal biological treatment plants. As discussed in Section VII, *Control and Treatment Technology*, refinery waste water is highly biodegradable and thus well suited for biological treatment.

A schematic of the activated sludge system is shown in Figure 22. Waste water is pumped through a primary clarifier to an aerated lagoon, with biological sludge being returned to the aerated lagoon from a secondary clarifier. Excess sludge is pumped to a sludge digester; the sludge from the digester is pumped to a holding lagoon. The total effluent waste loadings as a result of the addition of this Alternative are estimated to be 0.43 kilograms per metric ton (0.86 pounds per ton) of melt for BOD$_5$ and 0.09 kilograms per metric ton (0.18 pounds per ton) of melt for suspended solids.

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $255,000
Total Investment Cost: $368,000
Total Yearly Cost: $205,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $662,000
Total Investment Cost: $796,000
Total Yearly Cost: $296,000

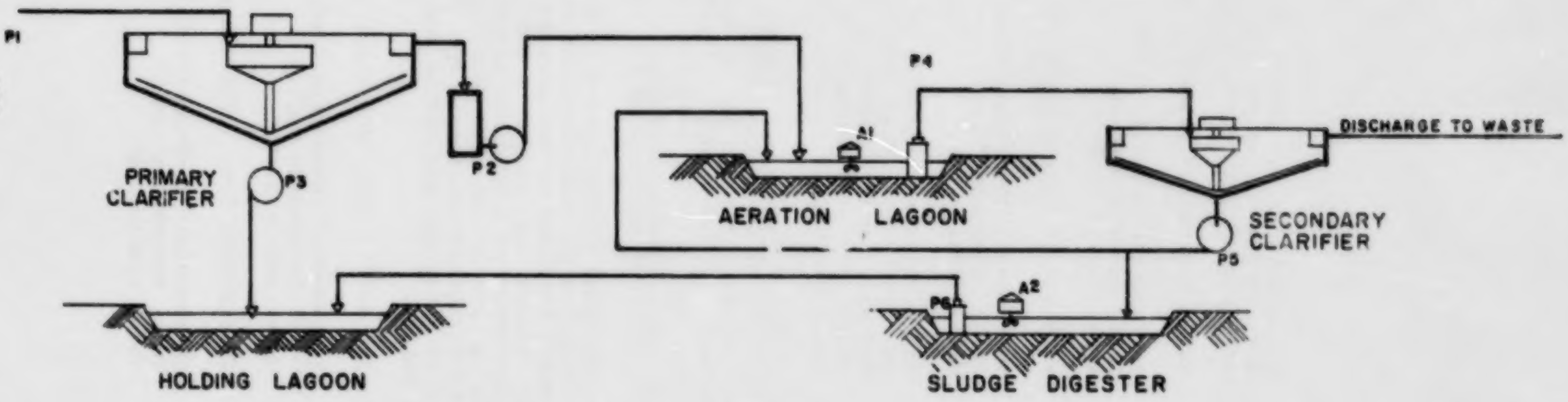
P1
PRIMARY CLARIFIER
P3
P2
HOLDING LAGOON
AERATION LAGOON
A1
P4
SECONDARY CLARIFIER
P5
DISCHARGE TO WASTE
P6
A2
SLUDGE DIGESTER

FIGURE 22

SCHEMATIC OF ACTIVATED SLUDGE SYSTEM

REDUCTION BENEFITS: An incremental reduction in BOD_5 of approximately 0.73 kilograms per metric ton (1.46 pounds per ton) of melt and in suspended solids of approximately 1.21 kilograms per metric ton (2.42 pounds per ton) of melt is evidenced over Alternative C. Total reductions of 76.8 percent for BOD_5 and 99.0 percent for suspended solids would be achieved.

Alternative E: Recycle of Condenser Water and Biological Treatment of Blowdown. This Alternative includes, in addition to Alternative D, the recycle of barometric condenser cooling water followed by biological treatment of the blowdown in an activated sludge unit and the addition of sand filtration to further treat the effluent from the activated sludge unit. The blowdown is assumed to be approximately two percent of the barometric condenser cooling water flow. Presently, there are three refineries using cooling towers and two which utilize a spray pond for the purpose of recycling barometric condenser cooling water. Recycle of barometric condenser cooling water accomplishes two important things; (1) it cools the water, thereby removing the heat normally discharged and (2) it concentrates the waste loadings into the smaller blowdown stream, making biological treatment of this waste stream feasible. The total effluent waste loadings as a result of the addition of this Alternative are estimated to be 0.09 kilograms per metric ton (0.18 pounds per ton) of melt for BOD_5 and 0.035 kilograms per metric ton (0.07 pounds per ton) of melt for suspended solids. In addition, 665,000 kilogram calories per metric ton (2.4 million BTU per ton) of melt are effectively removed from barometric condenser cooling water.

Under the most adverse conditions (lack of available land with no suitable alternative, excessive drift, fogging, noise, or a combination of these factors), which are presently not anticipated, the costs of application of this technology (cooling devices) could in some instances result in significant cost increases.

There are a number of methods of recycling barometric condenser cooling water; for the purposes of this document, the following are considered: cooling towers and spray ponds.

E-1: Alternative E with a Cooling Tower

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $346,000
Total Investment Cost: $714,000
Total Yearly Cost: $283,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $ 714,000
Total Investment Cost: $1,510,000
Total Yearly Cost: $ 470,000

E-2: Alternative E with a Spray Pond

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $ 282,000
Total Investment Cost: $ 650,000
Total Yearly Cost: $ 271,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $ 596,000
Total Investment Cost: $1,392,000
Total Yearly Cost: $ 438,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of approximately 0.34 kilograms per metric ton (0.68 pounds per ton) of melt and in suspended solids of 0.055 kilograms per metric ton (0.11 pounds per ton) of melt is evidenced by addition of this Alternative to Alternative D. Total reductions of 95.1 percent for BOD_5 and 99.6 percent for suspended solids would be achieved.

Alternative F: Elimination of Discharge of Process Water. This Alternative assumes that, in addition to Alternative C, all process waters are eliminated by controlled retention and total impoundage. The resulting effluent waste loading for BOD_5 associated with this control level is estimated at 0.34 kilograms per metric ton (0.68 pounds per ton) of melt, that amount attributable to barometric condenser cooling water. The suspended solids loading is zero as the only suspended solids-bearing waste stream has been eliminated.

F: Elimination of Discharge of Process Water
by Containment

Total impoundment of process water is sucessfully practiced by five refineries; however, a considerable amount of land is required (see Tables 17 and 18, Path 13). Containment of process waters is, therefore, not considered to be practicable technology for urban crystalline refineries.

COSTS: 545 metric tons (600 tons) per day crystalline refinery.

Incremental Investment Cost: $1,410,000
Total Investment Cost: $1,530,000
Total Yearly Cost: $ 211,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $4,870,000

Total Investment Cost $5,000,000
Total Yearly Cost: $ 591,000

REDUCTION BENEFITS: An incremental reduction in plant BOD_5 of 0.82 kilograms per metric ton (1.64 pounds per ton) of melt and in suspended solids of 1.30 kilograms per metric ton (2.60 pounds per ton) of melt is evidenced in comparison to Alternative C. Total reductions in BOD_5 of 81.6 percent and in suspended solids of 100 percent are achieved.

Alternative G: Elimination of Discharge of Barometric Condenser Cooling Water. This Alternative assumes that in addition to Alternative F, there is an elimination of discharge of barometric condenser cooling water. To achieve this level of treatment, it has been assumed that barometric condenser cooling water is recycled and the blowdown impounded. The blowdown of barometric condenser cooling water is assumed to be two percent of the total condenser flow. Effluent waste loadings associated with this control level are zero kilograms per metric ton (zero pounds per ton) of melt.

G-1: Recycle of Condenser Water Through a Cooling Tower with an Assumed Two Percent Blowdown to Controlled Land Retention, in Addition to Alternative F.

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $1,000,000
Total Investment Cost: $2,530,000
Total Yearly Cost: $ 352,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $2,620,000
Total Investment Cost: $7,620,000
Total Yearly Cost: $ 950,000

G-2: Recycle of Condenser Water Through a Spray Pond with an Assumed Two Percent Blowdown to Controlled Land Retention, in Addition to Alternative F.

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost: $ 940,000
Total Investment Cost: $2,470,000
Total Yearly Cost: $ 340,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost: $2,510,000
Total Investment Cost: $7,510,000
Total Yearly Cost: $ 918,000

TABLE 18

SUMMARY OF WASTE LOADS FROM TREATMENT ALTERNATIVES FOR THE SELECTED CRYSTALLINE REFINERIES

Effluent Constituent Parameters	Raw Waste	Treatment Alternative						
		A	B	C	D*	E**	F	G
BOD5 kg/kkg of melt	1.85	1.85	1.375	1.16	0.43	0.09	0.34	0
(lb/ton of melt)	(3.70)	(3.70)	(2.75)	(2.32)	(0.86)	(0.18)	(0.68)	(0)
TSS kg/kkg of melt	9.20	9.20	1.30	1.30	0.09	0.035	0	0
(lb/ton of melt)	(18.40)	(18.40)	(2.60)	(2.60)	(0.18)	(0.07)	(0)	(0)
DISCHARGE FLOW (m^3/kkg)								
Barometric Condensers	33.9	33.9	33.9	33.9	33.9	0.68	33.9	0.68
Process Water	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46
Filter Slurry	0.25	0.25	0	0	0	0	0	0

* BPCTCA

** BATEA;NSPS

TABLE 19

SUMMARY OF ALTERNATIVE COSTS FOR A 545 METRIC TONS (600 TONS) PER DAY CRYSTALLINE SUGAR REFINERY

Alternative	BOD5 Load*	% BOD5 Removal	TSS Load*	% TSS Removal	Investment Cost	Total Yearly Operating Cost	Total Yearly Cost
A	1.85	0.0	9.20	0.0	0	0	0
B-1	1.375	25.6	1.30	85.9	33,000	5,400	8,600
B-2	1.375	25.6	1.30	85.9	61,000	36,700	45,000
C	1.16	37.3	1.30	85.9	113,000	55,600	62,000**
D	0.43	76.8	0.09	99.0	368,000	174,000	205,000
E-1	0.09	95.1	0.035	99.6	714,000	219,000	283,000
E-2	0.09	95.1	0.035	99.6	650,000	214,000	271,000
F	0.34	81.6	0.0	100	1,530,000	70,000	211,000
G-1	0.0	100	0.0	100	2,530,000	114,000	352,000
G-2	0.0	100	0.0	100	2,470,000	109,000	340,000

*Waste Loadings in Kilograms per Metric Ton of Melt

**Includes Sugar Savings of $7,400/yr. as a Result of Entrainment Prevention.

TABLE 20

SUMMARY OF ALTERNATIVE COSTS FOR A 1,900 METRIC TONS (2,100 TONS) PER DAY CRYSTALLINE SUGAR REFINERY

Alternative	BOD5 Load*	% BOD5 Removal	TSS Load*	% TSS Removal	Investment Cost	Total Yearly Operating Cost	Total Yearly Cost
A	1.85	0.0	9.20	0.0	0	0	0
B-1	1.375	25.6	1.30	85.9	66,000	14,000	20,000
B-2	1.375	25.6	1.30	85.9	61,000	64,000	71,000
C	1.16	37.3	1.30	85.9	134,000	87,000	75,000**
D	0.43	76.8	0.09	99.0	796,000	244,000	296,000
E-1	0.09	95.1	0.035	99.6	1,510,000	350,000	470,000
E-2	0.09	95.1	0.035	99.6	1,390,000	330,000	438,000
F	0.34	81.6	0.0	100	5,000,000	137,000	591,000
G-1	0.0	100	0.0	100	7,620,000	245,000	950,000
G-2	0.0	100	0.0	100	7,510,000	226,000	918,000

*Waste Loadings in Kilograms per Melt

**Includes Sugar Savings of $27,000/yr. as a Result of Entrainment Prevention.

TABLE 21

IMPLEMENTATION SCHEDULES FOR A SMALL CRYSTALLINE SUGAR REFINERY

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
1	Containment of filter muds, all process water, and blowdown from cooling tower	0	0	61	No	2,500,000	316,000
2	Containment of filter muds, all process water, and blowdown from spray pond	0	0	61	No	2,440,000	304,000
3	Containment of filter muds and discharge process water and blowdown from cooling tower to municipal treatment	0	0	0.7	Yes	297,000	113,000
4	Containment of filter muds and discharge of process water and blowdown from spray pond to municipal treatment	0	0	0.7	Yes	233,000	102,000
5	Dry disposal of filter cake and containment of all process waters and blowdown from cooling tower	0	0	60	No	2,530,000	352,000

TABLE 21

IMPLEMENTATION SCHEDULES FOR A SMALL CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
6	Dry disposal of filter cake and containment of all process water and blowdown from spray pond	0	0	60	No	2,470,000	340,000
7	Dry disposal of filter cake with discharge of process waters and blowdown from cooling tower to municipal treatment	0	0	0.2	Yes	325,000	149,000
8	Dry disposal of filter cake and containment of all process water and blowdown from spray pond to municipal treatment	0	0	0.2	Yes	261,000	138,000
9	Containment of filter muds and biological treatment of process water and blowdown from cooling towers, followed by sand filtr.	0.09	0	0.8	No	686,000	247,000
10	Containment of filter muds and biological treatment of process water and blowdown from spray pond, followed by sand filtr.	0.09	0	0.9	No	622,000	235,000

TABLE 21

IMPLEMENTATION SCHEDULES FOR A SMALL CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
11	Dry disposal of filter cake and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.09	0	0.3	No	714,000	283,000
12	Dry disposal of filter cake and biological treatment of process water and blowdown from spray pond, followed by sand filtr.	0.09	0	0.4	No	650,000	271,000
13	Containment of filter muds and process waters and discharge of condenser water without cooling or recycle	0.34	0.67	38	No	1,500,000	174,000
14	Containment of filter muds, municipal treatment of process waters, and discharge of condenser water without cooling or recycle	0.34	0.67	0.5	Yes	85,000	53,000
15	Dry disposal of filter cake, containment of process water and discharge of condenser water without cooling or recycle	0.34	0.67	38	No	1,530,000	211,000

TABLE 21

IMPLEMENTATION SCHEDULE FOR A SMALL CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
16	Dry disposal of filter cake, municipal treatment of process water, and discharge of condenser water without cooling or recycle	0.34	0.67	0	Yes	113,000	89,000
17	Containment of filter muds, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.43	0.67	0.7	No	340,000	169,000
18	Dry disposal of filter cake, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.43	0.67	0.2	No	368,000	205,000

TABLE 22

IMPLEMENTATION SCHEDULES FOR A LARGE CRYSTALLINE SUGAR REFINERY

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
1	Containment of filter muds, all process waters, and blowdown from cooling tower	0	0	198	No	7,620,000	899,000
2	Containment of filter muds, all process water, and blowdown from spray pond	0	0	198	No	7,510,000	868,000
3	Containment of filter muds and discharge process water and blowdown from cooling tower to municipal treatment	0	0	1.8	Yes	539,000	252,000
4	Containment of filter muds and discharge of process water and blowdown from spray pond to municipal treatment	0	0	1.9	Yes	423,000	221,000
5	Dry disposal of filter cake and containment of all process waters and blowdown from cooling tower	0	0	196	No	7,620,000	950,000

TABLE 22

IMPLEMENTATION SCHEDULES FOR A LARGE CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
6	Dry disposal of filter muds and containment of all process water and blowdown from spray pond	0	0	196	No	7,510,000	918,000
7	Dry disposal of filter mud with discharge of process waters and blowdown from cooling tower to municipal treatment	0	0	0.2	Yes	534,000	303,000
8	Dry disposal of filter cake, containment of all process water, and blowdown from spray pond to municipal treatment	0	0	0.2	Yes	418,000	272,000
9	Containment of filter muds and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.09	0	1.7	No	1,510,000	419,000
10	Containment of filter muds and biological treatment of process water and blowdown from spray pond followed by sand filtr.	0.09	0	1.9	No	1,400,000	387,000

TABLE 22

IMPLEMENTATION SCHEDULES FOR A LARGE CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
11	Dry disposal of filter cake and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.09	0	0.3	No	1,510,000	470,000
12	Dry disposal of filter cake and biological treatment of process water and blowdown from spray pond, followed by sand filtr.	0.09	0	0.4	No	1,390,000	438,000
13	Containment of filter muds and process waters and discharge of condenser water without cooling or recycle	0.34	0.67	136	No	5,010,000	540,000
14	Containment of filter muds, municipal treatment of process waters, and discharge of condenser water without cooling or recycle	0.34	0.67	1.6	Yes	139,000	120,000
15	Dry disposal of filter cake, containment of process water and discharge of condenser water without cooling or recycle	0.34	0.67	135	No	5,000,000	591,000

TABLE 22

IMPLEMENTATION SCHEDULES FOR A LARGE CRYSTALLINE SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
16	Dry disposal of filter cake, municipal treatment of process water, and discharge of condenser water without cooling or recycle	0.34	0.67	0	Yes	134,000	171,000
17	Containment of filter muds, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.43	0.67	1.7	No	801,000	245,000
18	Dry disposal of filter cake, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.43	0.67	0.2	No	796,000	296,000

REDUCTION BENEFITS: An incremental reduction in plant BOD_5 of 0.34 kilograms per metric ton (0.68 pounds per ton) of melt is evidenced by addition of this Alternative to Altermative F. Total reduction of BOD_5 and suspended solids is 100 percent.

Discharge of Process Waste Streams to Municipal Treatment Systems. For the purpose of presenting cost information which is representative of the industry, it is necessary to determine costs associated with various schemes of discharge to municipal treatment systems. Twelve refineries currently discharge all or a portion of their wastes to municipal treatment systems. Seven of these are crystalline refineries with one other crystalline refinery having sewer hook-up and soon to practice this treatment technique. The following schemes are possible and the resulting costs presented.

M.T.#1: Discharge of Process Water to Municipal Treatment

This method of treatment of process water is practiced by twelve refineries, all urbanly located. This technology is not available to most rural refineries or to those refineries whose waste is not accepted by a municipal treatment system. It is however, a well demonstrated treatment method and practiced by 42 per cent of the nation's refineries. The costs presented here include the costs associated with Alternative C.

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost:	$0
Total Investment Cost:	$113,000
Total Operating Cost:	$ 83,000
Total Yearly Cost:	$ 90,000*

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost:	$0
Total Investment Cost:	$134,000
Total Operating Cost:	$183,000
Total Yearly Cost:	$171,000*

* Includes savings as a result of recovery of sugar which would normally be entrained in the barometric condenser cooling water.

M.T.#2: Recycle of Condenser Cooling Water Through a Cooling Tower with an Assumed Two Percent Blowdown to Municipal Treatment, in Addition to M.T.#1

COSTS: 545 metric tons (600 tons) per day crystalline refinery

Incremental Investment Cost:	$212,000
Total Investment Cost:	$325,000
Total Operating Cost:	$123,000
Total Yearly Cost:	$149,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost:	$400,000
Total Investment Cost:	$534,000
Total Operating Cost:	$276,000
Total Yearly Cost:	$303,000

M.T.#3: Recycle of Condenser Cooling Water Through a Spray Pond with an Assumed Two Percent Blowdown to Municipal Treatment, in Addition to M.T.#1

COSTS: 545 metric tons (600 tons) per day crystalling refinery

Incremental Investment Cost:	$148,000
Total Investment Cost:	$261,000
Total Operating Cost:	$118,000
Total Yearly Cost:	$138,000

1900 metric tons (2100 tons) per day crystalline refinery

Incremental Investment Cost:	$284,000
Total Investment Cost:	$418,000
Total Operating Cost:	$256,000
Total Yearly Cost:	$272,000

Liquid Refining

A liquid refinery with an average melt of 508 metric tons (560 tons) of sugar per day was chosen as the basis for cost estimates. The following treatment alternatives may be applied to this refinery.

Alternative A: No Waste Treatment or Control. The effluent from a 508 metric tons (560 tons) per day liquid refinery is 8,590 cubic meters (2.27 million gallons) per day. The resulting BOD_5 and suspended solids loadings are 3.725 kilograms per metric ton (7.45 pounds per ton) and 8.90 kilograms per metric ton (17.80 pounds per ton) respectively. Because no waste treatment is involved, no cost can be attributed to this Alternative.

COSTS: 0
REDUCTION BENEFITS: None

Alternative B: Elimination of Discharge from Filters. This Alternative can be achieved either by impounding the mud resulting from slurrying filter cake with water or by dry hauling the desweetened filter cake to landfill. The resulting effluent waste loads for BOD_5 and suspended solids are estimated to be 3.25 kilograms per metric ton (6.50 pounds per ton) and 1.00 kilograms per metric ton (2.00 pounds per ton) of melt respectively, at this control level.

B-1: Impound Filter Slurry

COSTS:	Incremental Investment Cost:	$31,000
	Total Investment Cost:	$31,000
	Total Yearly Cost:	$12,000

B-2: Dry Disposal of Filter Cake

COSTS:	Incremental Investment Cost:	$61,000
	Total Investment Cost:	$61,000
	Total Yearly Cost:	$45,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of approximately 0.475 kilograms per metric ton (0.95 pounds per ton) of melt and in suspended solids of approximately 7.90 kilograms per metric ton (15.80 pounds per ton) of melt is evidenced over Alternative A. Total plant reductions of 12.8 percent for BOD_5 and 88.8 percent for suspended solids would be achieved.

For the purpose of accruing total costs in this section of the report, the use of dry disposal of filter cake (B-2) will be considered representative of Alternative B.

Alternative C: Inplant Modifications to Reduce Entrainment of Sucrose into Condenser Water. This Alternative includes, in addition to Alternative B, the installation of demisters and external separators in order to reduce the entrainment of sucrose in barometric condenser cooling water. It is assumed, in addition, that the refinery has good baffling and operational controls in the evaporators and vacuum pans, as well as good vapor height. The resulting effluent waste loads for BOD_5 and suspended solids are 2.90 kilograms per metric ton (5.80 pounds per ton) of melt and 1.00 kilograms per metric ton (2.00 pounds per ton) of melt respectively, at this control level.

COSTS:	Incremental Investment Cost:	$ 54,000
	Total Investment Cost:	$115,000
	Total Yearly Cost:	$ 62,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of 0.35 kilograms per metric ton (0.70 pounds per ton) of melt is evidenced over Alternative B. The total reduction in BOD_5 is 22.1 percent and in suspended solids is 88.8 percent.

Alternative D: Biological Treatment of Process Water. This alternative assumes the addition of an activated sludge plant to treat process water. Presently there are no refineries which have their own biological treatment systems, but refinery wastes are commonly treated in municipal biological treatment plants. As discussed in Section VII, refinery waste is highly biodegradable and thus well suited for biological treatment.

A schematic of the activated sludge system is shown in Figure 22. Waste water is pumped through a primary clarifier to an aerated lagoon with biological sludge being returned to the aerated lagoon from a secondary clarifier. Excess sludge is pumped to a sludge digester; the sludge from the digester is pumped to a holding lagoon. The total effluent waste loadings as a result of the addition of this Alternative are estimated to be 0.32 kilograms per metric ton (0.63 pounds per ton) of melt for BOD_5 and 0.165 kilograms per metric ton (0.33 pounds per ton) of melt for suspended solids.

COSTS:		
	Incremental Investment Cost:	$337,000
	Total Investment Cost:	$452,000
	Total Yearly Cost:	$230,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of approximately 2.58 kilograms per metric ton (5.16 pounds per ton) of melt and in suspended solids of 0.835 kilograms per metric ton (1.67 pounds per ton) of melt is evidenced over Alternative C. Total reductions of 91.4 percent for BOD_5 and 98.1 percent for suspended solids would be achieved.

Alternative E: Recycle of Barometric Condenser Cooling Water and Biological Treatment of Blowdown. This Alternative includes, in addition to Alternative D, the recycle of barometric condenser cooling water followed by biological treatment of the blowdown in an activated sludge unit and the addition of sand filtration to further treat the effluent from the activated sludge unit. The blowdown is assumed to be approximately two percent of the total condenser flow. Presently there are three refineries using cooling towers and two which utilize a spray pond for the purpose of recycling barometric condenser cooling water. Recycle of barometric condenser cooling water accomplishes two important things: (1) it cools the water, thereby removing the heat normally discharged and (2) it concentrates the waste loadings into the smaller blowdown stream, making biological treatment of this waste stream feasible. The total effluent waste loadings as a result of the addition of this Alternative are estimated to be 0.15 kilograms per metric ton (0.30 pounds per ton) of melt for BOD_5 and 0.03 kilograms per metric ton (0.06 pounds per ton) of melt for suspended solids. In addition, 250,000 kilogram calories per metric ton (0.9 million BTU per ton) of melt are effectively removed from condenser water.

Under the most adverse conditions (lack of available land with no suitable alternative, excessive drift, fogging, noise, or a combination of these factors), which are presently not anticipated, the costs of application of this technology (cooling devices) could in some instances result in significant cost increases.

There are a number of methods of recycling barometric condenser cooling water; for the purposes of this document, the following are considered: cooling towers and spray ponds.

E-1: Alternative E with a Cooling Tower

COSTS:
Incremental Investment Cost: $174,000
Total Investment Cost: $626,000
Total Yearly Cost: $265,000

E-2: Alternative E with a Spray Pond

COSTS:
Incremental Investment Cost: $152,000
Total Investment Cost: $604,000
Total Yearly Cost: $261,000

REDUCTION BENEFITS: An incremental reduction in BOD_5 of 0.17 kilograms per metric ton (0.34 pounds per ton) of melt and in suspended solids of 0.135 kilograms per metric ton (0.27 pounds per ton) of melt is evidenced by addition of this Alternative to Alternative D. Total reductions of 96.0 percent for BOD_5 and 99.7 percent for suspended solids are achieved.

Alternative F: Elimination of Discharge of Process Water. This Alternative assumes that, in addition to Alternative C, all process waters are eliminated by controlled retention and total impoundage. The resulting effluent waste loading for BOD_5 associated with this control level is estimated at 0.15 kilograms per metric ton (0.30 pounds per ton) of melt, that amount attributable to barometric condenser cooling water. The suspended solids loading is zero as the only suspended solids-bearing waste stream has been eliminated.

F: Elimination of Discharge of Process Water by Containment

Total impoundment of process water is successfully practiced by five refineries; however, a considerable amount of land is required (see Table 25, Path 13). Containment of process water is, therefore, not considered to be practicable technology for urban liquid refineries.

TABLE 23

SUMMARY OF WASTE LOADS FROM TREATMENT ALTERNATIVES FOR THE SELECTED LIQUID REFINERY

Effluent Constituent Parameters	Raw Waste	Treatment Alternative						
		A	B	C	D*	E**	F	G
BOD5 kg/kkg of melt	3.725	3.725	3.25	2.90	0.32	0.15	0.15	0
(lb/ton of melt)	(7.45)	(7.45)	(6.50)	(5.80)	(0.63)	(0.30)	(0.30)	(0)
TSS kg/kkg of melt	8.90	8.90	1.00	1.00	0.17	0.03	0	0
(lb/ton of melt)	(17.80)	(17.80)	(2.00)	(2.00)	(0.33)	(0.06)	(0)	(0)
DISCHARGE FLOW (m^3/kkg)								
Barometric Condensers	15.0	15.0	15.0	15.0	15.0	0.30	15.0	0.30
Process Water	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
Filter Slurry	.25	.25	0	0	0	0	0	0

* BPCTCA

** BATEA;NSPS

TABLE 24

SUMMARY OF ALTERNATIVE COSTS FOR A 508 METRIC TONS (560 TONS) PER DAY LIQUID SUGAR REFINERY

Alternative	BOD$_5$ Load*	% BOD$_5$ Removal	TSS Load*	% TSS Removal	Investment Cost	Total Yearly Operating Cost	Total Yearly Cost
A	3.725	0.0	8.90	0.0	0	0	0
B-1	3.25	12.8	1.00	88.8	31,000	5,800	12,000
B-2	3.25	12.8	1.00	88.8	61,000	37,000	45,000
C	2.90	22.2	1.00	88.8	115,000	59,000	62,000**
D	0.32	91.4	0.165	98.1	452,000	194,000	230,000
E-1	0.15	96.0	0.03	99.7	626,000	213,000	265,000
E-2	0.15	96.0	0.03	99.7	604,000	210,000	261,000
F	0.15	96.0	0.0	100	1,570,000	74,000	217,000
G-1	0.0	100	0.0	100	2,040,000	93,000	280,000
G-2	0.0	100	0.0	100	2,013,000	90,000	275,000

*Waste Loadings in Kilograms per Metric Ton of Melt

**Includes Sugar Savings of $10,000/yr. as a Result of Entrainment Prevention.

TABLE 25

IMPLEMENTATION SCHEDULES FOR A LIQUID SUGAR REFINERY

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
1	Containment of filter muds, all process water, and blowdown from cooling tower	0	0	51	No	2,010,000	247,000
2	Containment of filter muds, all process water, and blowdown from spray pond	0	0	51	No	1,980,000	242,000
3	Containment of filter muds and discharge process water and blowdown from cooling tower to municipal treatment	0	0	0.5	Yes	186,000	77,000
4	Containment of filter muds and discharge of process water and blowdown from spray pond to municipal treatment	0	0	0.5	Yes	164,000	72,000
5	Dry disposal of filter cake and containment of all process waters and blowdown from cooling tower	0	0	50	No	2,040,000	280,000

TABLE 25

IMPLEMENTATION SCHEDULES FOR A LIQUID SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
6	Dry disposal of filter cake and containment of all process water and blowdown from spray pond	0	0	50	No	2,010,000	275,000
7	Dry disposal of filter cake with discharge of process waters and blowdown from cooling tower to municipal treatment	0	0	0.1	Yes	216,000	110,000
8	Dry diposal of filter cake and containment of all process water and blowdown from spray pond to municipal treatment	0	0	0.1	Yes	194,000	105,000
9	Containment of filter muds and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.15	0	0.6	No	596,000	232,000
10	Containment of filter muds and biological treatment of process water and blowdown from spray pond, followed by sand filtr.	0.15	0	0.6	No	574,000	228,000

TABLE 25

IMPLEMENTATION SCHEDULES FOR A LIQUID SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
11	Dry disposal of filter cake and biological treatment of process water and blowdown from cooling tower, followed by sand filtr.	0.15	0	0.2	No	626,000	265,000
12	Dry disposal of filter cake and biological treatment of process water and blowdown from spray pond, followed by sand filtr.	0.15	0	0.3	No	604,000	261,000
13	Containment of filter muds and process waters and discharge of condenser water without cooling or recycle	0.15	0.25	41	No	1,540,000	184,000
14	Containment of filter muds, municipal treatment of process waters, and discharge of condenser water without cooling or recycle	0.15	0.25	0.4	Yes	85,000	51,000
15	Dry disposal of filter cake, containment of process water and discharge of condenser water without cooling or recycle	0.15	0.25	40	No	1,570,000	217,000

TABLE 25

IMPLEMENTATION SCHEDULES FOR A LIQUID SUGAR REFINERY
(Continued)

Path	Description of Path	BOD Loading Discharged kg/kkg	Heat Loading Discharged k-Cal/kkg	Hectares of Available Land Required	Municipal Sewer Required	Investment Cost	Total Yearly Costs Including Power
16	Dry disposal of filter cake, municipal treatment of process water, and discharge of condenser water without cooling or recycle	0.15	0.25	0	Yes	115,000	84,000
17	Containment of filter muds, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.32	0.25	0.5	No	422,000	197,000
18	Dry disposal of filter cake, biological treatment of process water, and discharge of condenser water without cooling or recycle	0.32	0.25	0.2	No	452,000	230,000

COSTS:	Incremental Investment Cost:	$1,455,000
	Total Investment Cost:	$1,570,000
	Total Yearly Cost:	$ 217,000

REDUCTION BENEFITS: An incremental reduction in plant BOD_5 of 2.75 kilograms per metric ton (5.50 pounds per ton) of melt and in suspended solids of 1.00 kilograms per metric ton (2.00 pounds per ton) of melt is evidenced in comparison to Alternative C. Total reductions in BOD_5 of 96.0 percent and in suspended solids of 100 percent are achieved.

Alternative G: Elimination of Discharge of Barometric Condenser Cooling Water. This Alternative assumes that in addition to Alternative F there is an elimination of discharge of barometric condenser cooling water. To achieve this level of treatment, it has been assumed that condenser water is recycled and the blowdown impounded or discharged to a municipal treatment system. The blowdown of barometric condenser cooling water is assumed to be two percent of the total condenser flow. Effluent waste loads associated with this control level are zero kilograms per metric ton (zero pounds per ton) of melt.

G-1: Recycle of Condenser Water Through a Cooling Tower with an Assumed Two Percent Blowdown to Controlled Land Retention, in Addition to Alternative F.

COSTS:	Incremental Investment Cost:	$ 470,000
	Total Investment Cost:	$2,040,000
	Total Yearly Cost:	$ 280,000

G-2: Recycle of Condenser Cooling Water Through a Spray Pond with an Assumed Two Percent Blowdown to Controlled Land Retention in Addition to Alternative F.

COSTS:	Incremental Investment Cost:	$ 443,000
	Total Investment Cost:	$2,013,000
	Total Yearly Cost:	$ 275,000

REDUCTION BENEFITS: An incremental reduction in plant BOD_5 of 0.15 kilograms per metric ton (0.30 pounds per ton) of melt is evidenced by addition of this Alternative to Alternative F. Total reductions of BOD_5 and suspended solids are 100 percent.

Discharge of Process Waste Streams to Municipal Treatment System. For the purpose of presenting cost information which is representative of the industry, it is necessary to determine costs associated with various schemes of discharge to municipal treatment systems. Twelve refineries currently discharge all or a portion of their wastes in municipal treatment systems. Three of these are liquid refineries and two are combination crystalline - liquid refineries. The following schemes are possible and the resulting costs presented.

M.T.#1: Discharge of Process Water to Municipal Treatment

This method of treatment of process water is practiced by three of the five liquid refineries and by both combination crystalline - liquid refineries, all urbanly located. This technology is not available to most rural refineries or to those refineries whose waste is not accepted by a municipal treatment system. It is however, a well demonstrated treatment method and practiced by 42 percent of the nation's refineries. The costs presented include those costs attributable to Alternative C.

COSTS:	Incremental Investment Cost:	$0
	Total Investment Cost:	$115,000
	Total Operating Cost:	$ 81,000
	Total Yearly Cost:	$ 84,000*

* Includes savings as a result of recovery of sugar which would normally be entrained in the barometric condenser cooling water.

M.T.#2: Recycle of Condenser Cooling Water Through a Cooling Tower with an Assumed Two Percent Blowdown to Municipal Treatment, in Addition to M.T. #1

COSTS:	Incremental Investment Cost:	$101,000
	Total Investment Cost:	$216,000
	Total Operating Cost:	$ 97,000
	Total Yearly Cost:	$110,000

M.T.#3: Recycle of Condenser Cooling Water Through a Spray Pond with an Assumed Two Percent Blowdown to Municipal Treatment, in Addition to M.T.#1

COSTS:	Incremental Investment Cost:	$ 79,000
	Total Investment Cost:	$194,000
	Total Operating Cost:	$ 94,000
	Total Yearly Cost:	$105,000

RELATED ENERGY REQUIREMENTS OF ALTERNATIVE TREATMENT AND CONTROL TECHNOLOGIES - CANE SUGAR REFINING

To process 0.9 metric tons (one ton) of raw sugar into refined sugar, it is estimated that 60 and 64 kilowatt-hours of electricity are required for crystalline and liquid sugar refineries, respectively. This electrical energy is affected by process variations, in-place pollution control devices, and amount of lighting.

At a cost of 2.3 cents per kilowatt-hour, a crystalline sugar refinery processing 136,250 metric tons (150,000 tons) of raw sugar per year, would have a yearly energy cost of $209,000. Associated with the control alternatives are additional annual energy costs. These are estimated to be:

Alternatives	Cost
A	$ -0-
B-1	300
B-2	1,200
C	1,200
D	8,140
E-1	27,000
E-2	27,000
F	1,460
G-1	19,700
G-2	14,000
M.T. #1	1,200
M.T. #2	19,300
M.T. #3	13,600

At a cost of 2.3 cents per kilowatt-hour, a crystalline cane sugar refinery processing 475,000 metric tons (525,000 tons) of raw sugar per year would have a yearly energy cost of $725,000. Associated with the control alternatives are additional annual energy costs. These are estimated to be:

Alternatives	Cost
A	$ -0-
B-1	500
B-2	1,200
C	1,200
D	28,000
E-1	83,000
E-2	71,000
F	1,600
G-1	51,800
G-2	40,400
M.T. #1	1,200
M.T. #2	51,200
M.T. #3	39,800

At a cost of 2.3 cents per kilowatt-hour, a liquid cane sugar refinery processing 127,000 metric tons (140,000 tons) of raw sugar per year would have a yearly energy cost of $206,000. Associated with the control alternatives are additional annual energy costs. These are estimated to be:

Alternatives	Cost
A	$ -0-
B-1	300
B-2	1,200
C	1,200
D	21,300
E-1	27,000
E-2	26,000
F	1,400
G-1	6,500
G-3	5,300
M.T. #1	1,200
M.T. #2	6,200
M.T. #3	5,100

NON-WATER QUALITY ASPECTS OF ALTERNATIVE TREATMENT AND CONTROL TECHNOLOGIES

Air Pollution

Waste water lagooning, particularly under anaerobic conditions, can promote the growth of sulfur reducing organisms and associated noxious gases. The maintenance of aerobic conditions can be maintained by the design of shallow ponds (two feet or less), by the use of aerators (although these can increase an existing problem), by pH adjustment, or by other means.

Solid Wastes

The removal of solids from waste water produces a solid waste disposal problem in the form of sludges. In these cases, where the sludges are to be impounded, previously discussed measures for protection of ground water must be taken. Sanitary landfills, when available, usually offer an economical solution if hauling distances are reasonable. The additional solids waste produced by waste water treatment is not expected to be a significant problem. Technology and knowledge are available to prevent harmful effects to the environment as a result of land disposal of sludge.

Non-Water Quality Aspects of Cooling Towers or Other Cooling Devices

The non-water quality environmental impacts which may be of significance as a result of the application of cooling towers or other cooling devices for the recirculation of barometric condenser cooling water or which must be minimized include drift, fogging, and noise.

Drift. Water vapor and heated air are not the only effluents from cooling towers. Small droplets of cooling water become entrained in the air flow, and are carried from the tower. These droplets have the same composition as the cooling water; the water may evaporate from the drops, leaving behind the dissolved solids which are present in the cooling water.

The amount of drift is basically a function of cooling tower design, and particularly of the drift eliminators. The drift from mechanical cooling towers is on the order of 0.005% of tower flow, while drift from natural draft towers is on the order of half that of mechanical towers. If the tower drift results in an increased salt load on the surrounding area of only a few percent of the natural salt deposition rate, the effect is probably minimal.

Adverse environmental impacts due to drift are a local rather than a uniform national problem. Technology exists at a moderate cost which enables the integration of low drift levels into the overall tower design. In addition, proper location of the tower with regard to prevailing winds and the uses of surrounding land can be employed to meet stringent drift requirements.

Fogging. Fogging is one of the more noticeable effects resulting from the installation of cooling devices. Fog results when warm, moist air mixes with cooler ambient air. As the warm, moist air cools, it may reach saturation and then supersaturation. When this occurs, the water vapor condenses and forms droplets of fog. The production of fog by cooling devices is primarily a function of local climatic conditions. Those areas normally susceptible to cooling tower fog are those areas in which natural fog occurs frequently.

The fog plume from mechanical draft towers is emitted close to the ground. Under certain meteorological conditions, the fog may drop to the ground and could cause hazardous driving conditions on nearby roadways. Careful placement of the cooling device will eliminate most of the problems. If placement is unsatisfactory and creation of safety hazards is still anticipated, the use of a wet-dry tower can significantly reduce fog plumes. It should be noted that a wet-dry tower is more expensive than the conventional wet tower.

Noise. The problem of noise pollution should be considered while designing a cooling tower. All cooling towers produce some noise due to falling water and/or the operation of fans. A three stage procedure usually results in adequate coverage of any noise problems if they are anticipated while in the cooling tower design stage. These include:

1. Establishing a noise level which is acceptable to those within hearing range of the tower,

2. Estimate the anticipated tower noise levels, taking into account distance to neighbors and location of the tower, and

3. A comparison of the tower noise level to that of the acceptable noise level.

Only if the tower noise level is in excess of the acceptable noise level is corrective action necessary.

If the tower noise is of greater magnitude than normal refinery noise, a problem could exist in noise sensitive areas. Every effort should be made to locate these structures away from potential sources of complaint. Sound levels decrease with the square of the distance from the source of the noise. Walls and buildings may act as sould barriers, thus reducing any problems. Fan speeds can be reduced, if the tower is over-designed, thus reducing noise. Proper attention to noise problems during tower design and placement can avoid costly corrective measures.

If the above procedures are unable to reduce noise levels to acceptable levels, sound attenuation can be achieved by modification of or addition to the tower. Discharge baffles and accoustically lined plenums can be utilized; barrier walls or baffles can be erected. Proper design and operation can minimize the expense involved in noise suppression.

Adverse noise impacts are a local rather than a uniform national problem. Technology is available at a moderate cost to reduce the noise impact due to the addition of cooling towers.

Additional Installation Costs

There are certain situations where the addition of a cooling tower or other cooling device could be impractical or uneconomical. One of these situations is a location in a downtown area where the surrounding land is already highly developed and unavailable. In these situations, other alternatives exist such as installing the cooling tower on the roof, in the basement, above a parking lot, or on land already in the possession of the cane sugar refinery. These alternatives may or may not result in significant cost increases.

Other factors such as drift, fogging, and noise problems can be designed around in most situations. This may or may not result in signficiant cost increases.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977, are to specify the degree of effluent reduction attainable through the application of the best practicable control technology currently available. Best practicable control technology currently available is generally based upon the average of best existing performance by plants of various sizes, ages and unit processes within the industrial category and/or subcategory.

Consideration must also be given to:

a. The total cost of application of the technology in relation to the effluent reduction benefits to be achieved from such application;

b. The size and age of equipment and facilities involved;

c. The process employed;

d. The engineering aspects of the application of various types of control techniques;

e. Process changes;

f. Non-water quality environmental impact (including energy requirements);

Best practicable control technology currently available emphasizes treatment facilities at the end of a manufacturing process but includes the control technologies within the process itself when these are considered to be normal practice within the industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available". As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of construction or installation of the control facilities.

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EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE FOR THE CANE SUGAR REFINING SEGMENT

Based upon the information contained in Sections III through VIII of this document, it has been determined that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is that resulting from maximum sucrose entrainment prevention in barometric condenser cooling water, elimination of a discharge of filter cake, and biological treatment of all process water other than uncontaminated (non-contact) cooling water and barometric condenser cooling water. The effluent levels attainable for this degree of reduction are shown in Table 1.

Effluent Limitations Guidelines Development

For the purpose of establishing uniform national effluent limitations guidelines, model refineries were hypothesized which represent the crystalline and liquid cane sugar refining subcategories of the sugar processing point source category. Within both subcategories of the cane sugar refining segment, presently employed end-of-pipe treatment consists of either discharge to municipal treatment systems or impoundage (total or partial) of the waste water stream. Neither of these technologies is available to the entire cane sugar refining segment. In the development of uniform national standards, it is necessary to base effluent limitations guidelines upon technology which is practicable by all elements of the industry segment. The technology on which the guidelines are based is biological treatment, namely activated sludge. Biological treatment is a practicable technology, demonstrated by its use in the treatment of waste waters similar in nature to those associated with cane sugar refining. Because this technology is not presently employed, an average rather than exemplary plant approach is taken in the determination of water usages and effluent raw waste loadings on which to base effluent reductions attainable and costs associated with the application of various control and treatment technologies. The model refineries which are representative of the crystalline and liquid cane sugar refining subcategories are derived from a basis of average rather than exemplary water usage. BOD$\underline{5}$ and TSS raw waste loadings are based upon average to poor, rather than exemplary in-plant control practices.

The initial step in guidelines development involved the separation of the waste water effluent to reflect the two major waste streams, barometic condenser cooling water and process water. To these two streams were applied the model technologies: sucrose entrainment prevention in the case of barometric condenser cooling water and biological treatment in the case of the process water stream. Reasonable levels of control or treatment are specified for both waste water streams. It is felt that the levels of treatment specified in the prior Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the CANE SUGAR REFINING Segment of the Sugar Processing Point Source Category are reasonable and attainable. The guidelines have been relaxed to allow for possible operational problems resulting from a specified treatment technique (activated sludge biological treatment) which, while practicable, is not currently industry practice.

It is felt that the effluent limitations guidelines presented in this section are reasonable and technically easily achievable through the application of improved in-plant controls and the addition of an appropriate treatment system to treat the process water stream. The conservative rather than the exemplary plant approach was taken to ensure that the effluent limitations guidelines are viable to the cane sugar refining industry as a whole and because the activated sludge treatment system, while practicable, is not currently industry practice.

BOD5. The final BOD5 limits were derived by separating the waste water effluent to reflect the two major waste streams, barometric condenser cooling water and process water. It is assumed that the model biological treatment system will attain reductions in the process water BOD5 loading to 60 and 100 mg/l for the crystalline and liquid cane sugar refining subcategories, respectively. It is assumed that by utilizing proper control, the net BOD5 associated with the barometric condenser cooling water stream will be limited to 10 mg/l. The addition of the net BOD5 attributable to the barometric condenser cooling water stream to that amount of BOD5 incorporated into the process water effluent stream results in the limitation guideline. Where the barometric condenser cooling water and process water streams are mixed and impossible to measure separately prior to discharge, the BOD5 value should be considered net.

This does not imply that plants must necessarily duplicate the assumed raw waste loadings, water usage, and treatment efficiencies. It is possible for plants to achieve the indicated final effluent waste loadings by operating at lower average treatment efficiencies but receiving lower pollutional raw waste loadings and/or using less process or barometric condenser cooling water. In addition, an entirely different approach such as disposal by controlled irrigation or controlled land impoundage may be employed.

TSS. The final effluent TSS limitations were derived by assuming process water TSS loading reductions to 60 and 100 mg/l for the crystalline and liquid cane sugar refining subcategories, respectively. No TSS limit has been established for the barometric condenser cooling water stream because of the low TSS raw waste loading associated with this waste water stream. Where the barometric condenser cooling water and process water streams are mixed and impossible to measure separately prior to discharge, the TSS value should be considered net.

Establishment of Daily Average Effluent Limitations Guidelines. Based upon an analysis of biological treatment systems operating on wastes similar in nature to those associated with cane sugar regining and upon engineering judgement, the following ratios of daily maximum to monthly average limitations are established:

- Barometric condenser cooling water will be three times the monthly average for BOD_5 for both the crystalline and liquid cane sugar refining subcategories.

- Process water will be two times the monthly average for BOD_5 and three times the monthly average for TSS for both the crystalline and liquid cane sugar refining subcategories.

Production Basis. The average permitted effluent level should be the recommended level, expressed as kg/kkg (lb/ton) of melt, multiplied by the present daily processing rate, expressed as kkg (ton) per day of melt. It is recommended that the daily processing rate be based on the highest average rate sustained over thirty (30) consecutive days (not necessarily continuous) of full normal production. This should provide a period of time long enough to dampen the effect of non-typical minimum or maximum periods and allows for a limitation based on actual production history rather than on rated capacity.

It is recommended that for combined crystalline-liquid cane sugar refineries, the limitations be based on a weighted average of those fractions of liquid and crystalline production.

Identification of Best Practicable Control Technology Currently Available

Best practicable control technology currently available for the cane sugar refining segment of the sugar processing category is the recycle and reuse of certain process waters within the refining process, the minimization of sucrose entrainment in barometric condenser cooling water, the elimination of a discharge of filter cake, and the biological treatment of excess process waters. Implementation of this requires the following:

a. Collection and recovery of all floor drainage.

b. Minimization of sucrose entrainment in barometric condenser cooling water by the use of improved baffling systems, demisters, and/or other control devices.

c. Dry handling of filter cakes after desweetening with disposal to sanitary landfills, or complete containment of filter cake slurries.

d. Biological treatment of all waste water discharges other than uncontaminated (non-contact) cooling water and barometric condenser cooling water.

Engineering Aspects of Control Technique Applications

The technology defined for this level is practicable. There are refineries which currently collect all floor drainage. Most refineries currently achieve either dry handling or complete containment of filter cake. All of the control devices described for entrainment control have been demonstrated by various refineries. Biological treatability of refinery waste waters has been demonstrated by the twelve refineries that discharge process water to municipal biological treatment systems.

Costs of Application

The costs of attaining the effluent reductions set forth herein are summarized in Section VIII, Cost, Energy, and Non-Water Quality Aspects.

The investment costs associated with this level of technology represent approximately 2% of the total investment needed to build the typical refinery. The total capital cost to the cane sugar refining segment is approximately $5,910,000. It is estimated that $5.6 million of this total is associated with the crystalline cane sugar refining subcategory and that $0.31 million is associated with the liquid cane sugar refining subcategory.

Non-water Quality Environmental Impact

The primary non-water quality environmental impacts are summarized in Section VIII, Cost, Energy and Non-water Quality Aspects. The major concern is the strong reliance upon the land for ultimate disposal of wastes. However, the technology is available to assure that land disposal systems are maintained commensurate with soil tolerances.

A secondary concern is the generation of solid wastes in the form of sludges and muds and the possibility of odors resulting from impoundage lagoons. In both cases, responsible operation and maintenance procedures coupled with sound environmental planning have been shown to obviate the problems.

It is estimated that the increase in energy necessary to implement the required control and treatment amounts to 0.84% of the current energy usage for the crystalline cane sugar refining subcategory and 0.6% for the liquid cane sugar refining subcategory.

Factors to be Considered in Applying Effluent Limitations

The above assessment of what constitutes the best practicable control technology currently available is predicated on the assumption of a degree of uniformity among refineries that, strictly speaking, does not exist. Tables 21, 22, and 25 list various treatment control alternatives (i.e., discharge of waste waters to municipal treatment systems) and summarize requirements and benefits associated with each. It is believed that the data in these tables can be a valuable aid in assessing problems and associated solutions for individual installations.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1983, are to specify the degree of effluent reduction attainable through the application of the best available technology economically achievable. The best available technology economically achievable is not based upon an average of the best performance within an industrial category, but is to be determined by identifying the very best control and treatment technology employed by a specific point source within the industrial category or subcategory, or where it is readily transferable, from one industrial process to another. A specific finding must be made as to the availability of control measures and practices to eliminate the discharge of pollutants, taking into account the cost of such elimination.

Consideration must also be given to:

(a) the age of equipment and facilities involved;
(b) the process employed;
(c) the engineering aspects of the application of various types of control techniques;
(d) process changes;
(e) cost of achieving the effluent reduction resulting from application of the best economically achievable technology;
(f) non-water quality environmental impact (including energy requirements).

In contrast to the best practicable control technology currently available, the best economically achievable technology assesses the availability in all cases of in-process controls as well as control or additional treatment techniques employed at the end of a production process.

Those plant processes and control technologies which at the pilot plant semi-works, or other levels, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities may be considered in assessing the best available economically achievable technology. The best available economically achievable technology is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including "no discharge" of pollutants. Although economic factors are considered in this development, the costs for this level of control are intended to be the top-of-the-line of current technology subject to limitations imposed by economic and engineering feasibility. However, the best available technology economically achievable may be characterized by some

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technical risk with respect to performance and with respect to certainty of costs. Therefore, the best available technology economically achievable may necessitate some industrially sponsored development work prior to its application.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE--EFFLUENT LIMITATIONS GUIDELINES

Based upon the information contained in this document, it has been determined that the degree of effluent reduction attainable through the application of the best available technology economically achievable is that resulting from the technology of cooling and recycling barometric condenser cooling water with biological treatment of the blowdown and the addition of sand filtration to further treat the effluent from the biological treatment system. The effluent levels attainable for this degree of reduction are shown in Table 1.

Effluent Limitations Guidelines Development

The effluent limitations guidelines associated with best practicable control technology currently available (discussed in Section IX) were modified from those levels which were proposed in the December 1973 Development Document, to reflect the possible operational problems associated with the application of a treatment technique (activated sludge biological treatment) which is not currently industry practice. It is felt that by 1983 there will be sufficient experience gained by operators of these systems to minimize these operational problems. The levels of reduction recommended for best available technology economically achievable reflect this feeling.

BOD5. Based on improved operation of the properly designed biological treatment system, effluent BOD5 levels of 40 mg/l for the crystalline and 75 mg/l for the liquid cane sugar refining subcategories have been determined to be realistic. No credit for BOD5 removal as a result of solids removal in the sand polishing operation has been assumed. This is because of the uncertainty at present of the ratio of soluble to insoluble BOD in the effluent from the biological treatment system. The effluent limitations guidelines recommended through application of the best available technology economically achievable may have to be modified at a later date to reflect that amount of BOD5 which is removed in the sand polishing step.

TSS. It has been determined that at the effluent waste loadings entering the sand filtration units from the activated sludge system, a waste loading from the sand filtration units of 15 mg/l TSS can be readily achieved.

Establishment of Daily Average Effluent Limitations Guidelines. Based upon an analysis of biological treatment systems operating on wastes similar in nature to those associated with cane sugar refining and upon engineering judgment, the following ratios of daily maximum to monthly average limitations are established:

- BOD5: The daily maximum will be two times the monthly average for both the crystalline and liquid cane sugar refining subcategories.

- TSS: The daily maximum will be three times the monthly average for both the crystalline and liquid cane sugar refining subcategories.

Production Basis. The average permitted effluent level should be the recommended level, expressed as kg/kkg (lb/ton) of melt, multiplied by the present daily processing rate, expressed as kkg (ton) per day of melt. It is recommended that the daily processing rate be based on the highest average rate sustained over thirty (30) consecutive days (not necessarily continuous) of full normal production. This should provide a period of time long enough to dampen the effect of non-typical minimum or maximum periods and allows for limitations based on actual production history rather than on rated capacity.

It is recommended that for combined crystalline - liquid cane sugar refineries, the limitations be based on a weighted average of those fractions of liquid and crystalline production

Identification of Best Available Technology Economically Achievable

Best available technology economically achievable for the cane sugar refining segment of the sugar processing industry is that technology described in Section IX of this document with the addition of a cooling and recycling system for barometric condenser cooling water, with the blowdown from the recirculation system being discharged to the biological treatment system, and the addition of sand filtration to further treat the effluent from the biological treatment system. Implementation of this technology requires the following:

a. That technology described as best practicable control technology currently available, discussed in Section IX.

b. The addition of a cooling device to allow for the recirculation and reuse of barometric condenser cooling water.

c. The expansion of the biological treatment system, which treats the process water stream, in order to treat the blowdown from the barometric condenser cooling water recirculation system.

d. The addition of sand filtration to further treat the effluent from the biological treatment system.

Alternatives to this system could include controlled irrigation with all or a portion of the waste water streams, controlled impoundage of the waste water streams, the addition of surface condensers to replace barometric condensers (thus eliminating sucrose entrainment in condenser cooling waters), or the further reduction of sucrose entrainment in barometric condenser cooling water.

The effluent limitations guidelines are based on the treatment of all waste water streams. It is possible that through the application of improved control devices, sucrose entrainment in condenser cooling water could be further minimized or, as some industry sources have indicated, might be totally eliminated. One factor in applying the effluent limitations specified as best available technology economically achievable is the issue of net versus gross limitations. The Agency recognizes that in certain instances pollutants may be present in the navigable waters which supply a plant's intake water in significant concentrations which may not be removed to the levels specified in the guidelines by the application of the best available technology economically achievable or its alternatives. At the time of publication of this document, the Agency was reviewing the net versus gross issue and was contemplating amendments to its NPDES permit regulations which would specify the situations in which the Regional Administrator may allow a credit for such pollutants.

Engineering Aspects of Control Technique Applications

The recirculation of barometric condenser cooling water is currently practiced by five cane sugar refineries utilizing cooling towers, spray ponds, and canal systems. The biological treatment of the blowdown from the barometric condenser cooling water recirculation system has been demonstrated to a limited extent in the cane sugar refining industry (one refinery discharges cooling tower blowdown to a municipal treatment system) and to a greater extent in the soaps and detergents, oil refining, and grain milling industries. Sand filtration is a well-demonstrated polishing technique, widely used in both water supply and in waste water treatment.

Costs of Application

The costs of attaining the effluent reductions set forth herein are summarized in Section VIII, Cost, Energy, and Non-Water Quality Aspects.

The investment costs associated with the level of technology represent approximately 3.5 percent of the total investment needed to build the typical refinery. The total capital cost to the cane sugar refining segment is approximately $15,000,000 or $9,100,000 above that required to achieve the best practicable control technology currently available. It is estimated that $14.2 million of the total is associated with the crystalline cane sugar refining subcategory and that $0.8 million is associated with the liquid cane sugar refining subcategory.

Under the most adverse conditions, which are presently not anticipated, the costs of application of this technology could, in some instances, result in significant cost increases, as discussed in Section VIII. However, the provisions of the "Act" provide for the consideration of unusual adverse economic affects which would result from compliance with these limitations. On an indvidual basis the "Act" provides that the Administrator may modify the effluent limitations guidelines upon a showing by the owner or operator that such modified requirements will represent the maximum use of technology within the economic capability of the owner or operator and will result in reasonable further progress toward the elimination of the discharge of pollutants.

Non-Water Quality Environmental Impact

The non-water quality environmental impact would be an intensification of those impacts described in Section IX, plus those impacts associated with cooling devices (i.e., drift, fogging, and noise). Drift, fogging, and noise can be reduced through proper design and location, and can be minimized in most situations.

It is estimated that the increase in energy necessary to implement the required control and treatment amounts to 6.1% of the current energy usage for the crystalline cane sugar refining subcategory and 1.9% for the liquid cane sugar refining subcategory.

Factors to be Considered in Applying Effluent Limitations

The same factors as discussed in Section IX should be considered for this level. For refineries in rural areas, spray ponds or irrigation canals may be more feasible for recycling barometric condenser cooling water than cooling towers. Tables 21, 22, and 25 list various treatment and control alternatives and summarize the requirements and benefits associated with each.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

In addition to guidelines reflecting the best practicable control technology currently available and the best available technology economically achievable, applicable to existing point source discharges July 1, 1977, and July 1, 1983, respectively, the Act requires that performance standards be established for new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance". New source technology shall be evaluated by adding to the consideration underlying the identification of best available technology economically achievable a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-plant and end-of-process control technology, identified in best available technology economically achievable, new source technology is to be based upon an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods or other alternatives must be considered. However, the end result of the analysis will be to identify effluent standards which reflect levels of control achievable through the use of improved production processes (as well as control technology), rather than prescribing a particular type of process or technology which must be employed. A further determination which must be made for new source technology is whether a standard permitting no discharge of pollutants is practicable.

Specific Factors to be Taken into Consideration

At least the following factors should be considered with respect to production processes which are to be analyzed in assessing new source technology:

(a) the type of process employed and process changes;
(b) operating methods;
(c) batch as opposed to continuous operations;
(d) use of alternative raw materials and mixes of raw materials;
(e) use of dry rather than wet processes (including substitution of recoverable solvents for water); and
(f) recovery of pollutants as by-products.

NEW SOURCE PERFORMANCE STANDARDS FOR THE CANE SUGAR REFINING SEGMENT OF THE SUGAR PROCESSING INDUSTRY

Because of the large number of specific improvements in management practices, design of equipment, and processes and systems that have some

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potential of development, it is not possible to determine, within reasonable accuracy, the potential waste reductions achievable through their application in new sources. However, the implementation of those in-plant and end-of-pipe controls described in Section VII, Control and Treatment Technology, would enable new sources to achieve the effluent discharge levels defined in Section X.

The short lead time for application of new source performance standards (less than a year versus approximately four and ten years for other guidelines) affords little opportunity to engage in extensive development and testing of new procedures. The single justification for more restrictive limitations for new sources than for existing sources would be one of relative economics of installation in new plants versus modification of existing plants. There is no data to indicate that the economics of the application of in-plant and end-of-pipe technologies described in Section VII, Control and Treatment Technology, would be significantly weighted in favor of new sources.

The attainment of zero discharge of pollutants does not appear to be feasible for cane sugar refineries, other than those with sufficient and suitable land for irrigation or total impoundage of waste waters.

In view of the aforegoing, it is recommended that the effluent limitations for new sources be the same as those determined to be best available control technology economically achievable, presented in Section X.

SECTION XII

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SECTION XIII

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SECTION XIV

GLOSSARY

Affination - Washing to remove the adhering film of molasses from the surface of the raw sugar crystal, the first step in the refining operation.

Affination Centrifugal - A high speed centrifugal which separates syrup and molasses from sugar. Syrup from this centrifugal is recycled to the mingling phase of refining.

Alkalinity - Alkalinity is a measure of the capacity of water to neutralize an acid.

Alphanaphthol Test - A test for sucrose concentration in condenser water. The method is based on a color change which occurs in the reaction of the inorganic constituents.

Ash Content - In analysis of sugar products, sulfuric acid is added to the sample, and this residue, as "sulfated ash" heated to 800°C is taken to be a measure of the inorganic constituents.

Barometric Condenser - See Condenser, Barometric.

Barometric Leg - A long vertical pipe through which spent condenser water leaves the condenser. Serves as a source of vacuum.

Barometric Leg Water - Condenser cooling water.

Biological Wastewater Treatment - Forms of waste water treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Trickling filters, and activated sludge processes are examples.

Blackstrap Molasses - Molasses produced by the final vacuum pans, and from which sugar is unrecoverable by ordinary means. Blackstrap is usually sold for various uses.

BOD5 - Biochemical Oxygen Demand is a semiquantitative measure of biological decomposition of organic matter in a water sample. It is determined by measuring the oxygen required by micro-organisms to oxidize the contaminants of a water sample under standard laboratory conditions. The standard conditions include incubation for five days at 20°C.

Boiler Ash - The solid residue remaining from combustion of fuel in a boiler furnace.

Boiler Feedwater - Water used to generate steam in a boiler. This water is usually condensate, except during boiler startup, when treated fresh water is normally used.

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Boiler Blowdown - Discharge from a boiler system designed to prevent a buildup of dissolved solids.

Bone Char - An adsorptive material used in cane sugar refineries which is utilized in the removal of organic and inorganic impurities from sugar liquor.

Calandria - The steam belt or heating element in an evaporator or vacuum pan, consisting of vertical tube sheets constituting the heating surface.

Calandria Evaporator - An evaporator using a calandria; the standard evaporator in current use in the sugar industry.

Calandria Vacuum Pan - A vacuum pan using a calandria; the standard vacuum pan in current use in the sugar industry.

Centrifugation - A procedure used to separate materials of differing densities by subjecting them to high speed revolutions. In sugar processing, centrifugation is used to remove sugar crystals from massecuite.

Char Cistern - Cylindrical vats, measuring approximately 10 feet in diameter by 20 feet deep, which contain approximately 40 tons of bone char.

Clarification - The process of removing undissolved materials (largely insoluble lime salts) from cane juice by settling, filtration, or flotation.

Coagulation - In water and waste water treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological process.

COD - Chemical Oxygen Demand. Its determination provides a measure of the oxygen demand equivalent to that portion of matter in a sample which is susceptible to oxidation by a strong chemical oxidant.

Condensate - Water resulting from the condensation of vapor.

Condenser - A heat exchange device used for condensation.

Barometric: Condenser in which the cooling water and the vapors are in physical contact; the condensate is mixed in the cooling water.

Surface: Condenser in which heat is transferred through a barrier that separates the cooling water and the vapor. The condensate can be recovered separately.

Condenser Water - Water used for cooling in a condenser.

Crystallization - The process through which sugar crystals separate from massecuite.

Decanting - Separation of a liquid from solids by drawing off the upper layer after the heavier material has settled.

Decolorization - The refining process of removing color from sugar. The predominantly used methods involve the use of bone char, granular activated carbon, vegetable carbon, or powdered activated carbon.

Defecants - Chemicals which are added to melt liquor in order to remove remaining impurities. They include phosphoric acid (or carbon dioxide) and lime. The result of the treatment is the neutralization of organic acids and formation of a tri-calcium phosphate precipitate which entrains much of the colloidal and other suspended matter in the liquor.

Defecation Process - A method for purifying the cane juice involving lime, heat, and a small amount of phosphate. The result is the formation of an insoluble precipitate which is then removed in the clarification process.

Demineralization - Removal of mineral impurities from sugar.

Dextrose - Glucose. An invert sugar with the formula C6H12O6. Dextrose is a minor component of raw sugar.

Diatomaceous Earth - A viable earthy deposit composed of nearly pure silica and consisting essentially of the shells of the microscopic plants called diatoms. Diatomaceous earth is utilized by the cane sugar industry as a filter aid.

Disaccharides - A sugar such as sucrose composed of two monosaccharides.

D.O. - Dissolved Oxygen is a measure of the amount of free oxygen in a water sample. It is dependent on the physical, chemical, and biochemical activities of the water sample.

"Effect" - In systems where evaporators are operated in series of several units, each evaporator is known as an effect.

Entrainment - The entrapment of liquid droplets containing sugar in the water vapor produced by evaporation of syrup.

Evaporator - A closed vessel heated by steam and placed under a vacuum. The basic principle is that syrup enters the evaporator at a temperature higher than its boiling point under the reduced pressure, or is heated to that temperature. The result is flash evaporation of a portion of the water in the syrup.

False Crystals - New sugar crystals which form spontaneously without the presence of others. This event is undesirable, and therefore vacuum pan conditions are maintained in a narrow range of sucrose concentration and temperature which precludes their formation.

Filter Cake - The residue remaining after filtration of the sludge produced by the clarification process.

Filter Mud - A mud produced by slurrying filter cake. The resultant waste stream is a significant source of solids and organics within a cane sugar refinery.

Filter Press - In the past the most common type of filter used to separate solids from sludge. It consists of a simple and efficient plate and frame filter which allows filtered juice to mix with clarified juice and be sent to the evaporators.

Fixed Beds - A filter or adsorption bed where the entire media is exhausted before any of the media is cleaned.

Flocculant - A substance that induces or promotes fine particles in a colloidal suspension to aggregate into small lumps, which are more easily removed.

Floorwash - Water used to wash factory or refinery floors and equipment.

Flotation - The raising of suspended matter to the surface of the liquid in a tank as scum - by aeration, the evolution of gas, chemicals, electrolysis, heat, or bacterial decomposition - and the subsequent removal of the scum by skimming.

Frothing Clarifiers - Flotation devices that separate tri-calcium phosphate precipitate from the liquor.

Furfural - An aldehyde C_4H_3OCHO used in making Furaw and as a resin.

Glucose - Dextrose.

GPD - Gallons per day.

GPM - Gallons per minute.

Granular Activated Carbon - Substance used for decolorization of sugar. It differs from bone char in that it produces more sweet water, adsorbs no ash, and is normally not washed. There is little waste water produced from this process.

Granulation - The process which removes remaining moisture from sugar, and also separating the crystals from one another.

Granulator - A rotary dryer used in sugar refineries to remove free moisture from sugar crystals prior to packaging or storing.

Hydrolization - The addition of H_2O to a molecule. In sugar production, hydrolization of sucrose results in an inversion into glucose and fructose and represents lost production.

Impoundment - A pond, lake, tank, basin, or other space which is used for storage of waste water.

Impurities - Fine particles of bagasse, fats, waxes, and gums contained in the cane juice after milling. These impurities are reduced by successive refining processes.

Invert Sugars - Glucose and fructose formed by the splitting of sucrose by the enzyme sucrase.

Ion exchange - Reversible exchange of ions contained in a crystal for different ions in solution without destruction of crystal structure or disturbance of electrical neutrality. Used in sugar refining for color removal or removal of impurities.

Ion Exchange Resins - Resins consisting of three-dimensional networks to which are attached ionizable groups.

Isomers - Two or more compounds containing the same elements and having the same molecular weights, but differing in structure and properties, e.g. glucose and fructose.

Juices

Clarified: The juice obtained as a result of the clarification process, and synonymous with evaporator supply when the filtered juice is returned to the mixed juice.

Mixed: The juice sent from the extraction plant to the boiling house.

Levulose - Fructose. An invert sugar composed of six carbon chains with the formula $C_6H_{12}O_6$. Levulose is a component of raw sugar.

Magma - A heated sugar syrup solution to which raw crystals have been added.

Magma mingler - A revolving coiled mixer in which magma is heated in order to facilitate loosening the molasses film from raw sugar crystals; the first step in the refining process.

Massecuite - Mixture of sugar crystals and syrup which originates in the boiling of the sugar (literally cooked mass).

Malt Liquor - Molten sugar to which has been added a small amount of water (half the weight of the sugar).

MGD - Million gallons per day.

mg/l - Milligrams per liter (equals parts per million, ppm, when the specific gravity is unity).

Moisture - Loss in weight due to drying under specified conditions, expressed as percentage of total weight.

Molasses - A dark-colored syrup containing non-sugars produced in processing cane and beet sugar.

Monosaccharides - Simplified form of sugar.

Moving Beds - A filtration or adsorption bed where the media is constantly being removed and fresh media added.

Mud - The precipitated sludge resulting from the clarification process.

Multiple Effect Evaporation - The operation of evaporators in a series.

Nutrients - The nutrients in contaminated water are routinely analyzed to characterize the food available for micro-organisms to promote organic decomposition. They are:

Ammonia Nitrogen (NH3), mg/l as N
Kjeldahl Nitrogen (ON), mg/l as N
Nitrate Nitrogen (NO3), mg/l as N
Total Phosphate (TP), mg/l as P
Ortho Phosphate (OP), mg/l as P

pH - pH is a measure of the negative log of hydrogen ion concentration.

Phases of Supersaturation - metastable phase in which existing sugar crystals grow but new crystals do not form; the intermediate phase in which existing crystals grow and new crystals do form; and the labile phase in which new crystals form spontaneously without the presence of others.

Plate and Frame Filter - A filtering device consisting of a fastened inside a metal frame.

POL - The value determined by single polarization of the normal weight of a sugar product made up to a total volume of 100 milliliters at 20°C, clarified when necessary, with dry lead subacetate and read in a tube 200 milliliters long at 20°C, using the Bates-Jackson saccharimeter scale. The term is used in calculations as if it were a real substance.

Polyelectrolytes - Coagulent aids consisting of long chained organic molecules.

Precoat Filter - A type of filter in which the media is applied to an existing surface prior to filtration.

Raw Sugar - An intermediate product consisting of crystals of high purity covered with a film of low quality syrup.

Recrystallization - Formation of new crystals from previously melted sugar liquor. Recrystallization is encouraged by evaporators and accomplished in vacuum pans.

Regeneration Kilns - - Ovens which operate with a controlled amount of air, and in which bone char is placed for renewal of its capacities for buffering and decolorizing.

Regeneration of Char - After some sixty hours of operation, the decolorizing ability of bone char decreases to an unacceptable level, and the char must be washed and regenerated by heat in kilns or char house furnaces.

Remelt - A solution of low grade sugar in clarified juice or water.

Resorcinol Test - A color indicator test for determining the concentration of sucrose in condensate and condenser waters.

Rotary Vacuum Filter - A rotating drum filter which utilizes suction to separate solids from the sludge produced by clarification.

Saturation - The use of water in the milling process to dissolve sucrose. Identical, in this connotation, with imbibition and maceration.

Seed Suar - Small sucrose crystals which provide a surface for continued crystal growth.

Settlings - The material which collects in the bottom portion of a clarifier.

Sludge - The separated precipitate from the clarification process. It consists largely of insoluble lime salts and includes calcium phosphates, coagulate albumin, fats, acids and gums, iron, alumina, and other material.

Slurry - A mixture of water and solids. Filter cakes, ash, or other solids may be slurried to facilitate handling.

Solids - Various types of solids are commonly determined on water samples. These types of solids are:

Total Solids (TS): The material left after evaporation and drying of a sample at 103° to 105° C.

Dissolved Solids (DS): The difference between the total and suspended solids.

Volatile Solids (VS): Organic material which is lost when the sample is heated to 550°C.

Settleable Solids (STS): The materials which settle in an Imhoff cone in one hour.

Stabilization Pond - A type of oxidation pond in which biological oxidation of organic matter is effected by natural or artificially accelerated transfer of oxygen to the water from air.

Strike - The massecuite content of a vacuum pan.

Sucrose - A disaccharide having the formula $C_{12}H_{22}O_{11}$. The terms sucrose and sugar are generally interchangeable, and the common sugar of commerce is sucrose in varying degrees of purity. Refined cane sugar is essentially 100 percent sucrose.

Sugar - The sucrose crystals, including adhering mother liquor, remaining after centrifugation.

Commercial: Sugar from high grade massecuite, which enters into commerce.
Low Grade: Sugar from low grade massecuite, synonymous with remelt sugar.
96 DA: A value used for reporting commercial sugar on a common basis, calculated from an empirical formula issued by the United States Department of Agriculture.

Supersaturation - The condition of a solution when it contains more solute (sucrose) than would be present under normal pressure and temperature. When equilibrium is established between the saturated solution and undissolved solute, crystal growth commences.

Surface Condenser - See Condenser, Surface.

Suspended Solids - Solids found in waste water or in the stream which in most cases can be removed by filtration. The origin of suspended matter may be man-made wastes or natural sources as from erosion.

Vapor - Steam liberated from boiling sugar liquor.

Vapor Belt - The distance between the liquid level in an air evaporator or vacuum pan and the top of the cylindrical portion of the body.

Vegetable Carbon - A media for sugar decolorization.

Waste Streams - Any liquid waste material produced by a refinery.

METRIC UNITS
CONVERSION TABLE

MULTIPLY (ENGLISH UNITS)		by	TO OBTAIN (METRIC UNITS)	
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram-calories
British Thermal Unit/pound	BTU/1b	0.555	kg cal/kg	kilogram calories/ kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	1	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555 (°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	1	liters
gallon/minute	gpm	0.0631	1/sec	liters/second
horsepower	hp	0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	1b	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	ton	0.907	kkg	metric tons (1000 kilograms)
yard	yd	0.9144	m	meters

*Actual conversion, not a multiplier

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